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16. Abstract

To improve traffic operation and safety, several states have implemented truck lane restriction and differential speed limit policies on freeways. In response to an 11-vehicle crash in September 2003, the Louisiana State Department of Transportation and Development (LADOTD) introduced such operational policies on the 18-mile elevated section of Interstate 10 over the Atchafalaya Basin, where trucks were restricted to the right lane and their speed limit was reduced to 55 mph. The speed limit for all other types of vehicles was also reduced to 60 mph. The primary objectives of this research study were to examine the traffic characteristics and truck compliance behavior to the newly implemented policies, as well as evaluate the overall safety impact of such policies. Additionally, two opinion surveys were conducted to determine the truck drivers' perception and opinions with respect to these policies. Traffic data was collected and analyzed for four different sites along the freeway corridor using multiple linear regression, pairwise comparison and two sample t tests. The basic statistical analysis showed that the speed in the left lane was much higher than it was in the right lane as a result of the imposed differential speed limit. The results also showed more trucks in the right lane than in the left lane, with a compliance rate in the range of 60% to 80% most of the time. Further statistical analysis showed that the truck speeds were generally lower than the rest of the vehicles because of their reduced speed limit. For mixed traffic composition, truck speeds were significantly higher than 55 mph, but lower than 60 mph on the right lanes. The truck speeds, however, exceeded 60 mph in the left lane. Thus, trucks generally violated both lane restriction and speed limit. However, it should be noted that truckers were informed through the local trucking association that they were permitted to overtake in the left lane. Thus, their presence in the left lane and their increased speed may be at least partially due to the overtaking maneuver. The results from both surveys were consistent and showed that the truckers were not in favor of the restrictions and did not perceive that significant safety benefits would be gained from such restrictions. In fact, several responses indicated that it would be safer to have uniform speed limits and freedom to select a travel lane. The crash data analysis clearly showed a reduction in the number of crashes, and particularly the number of truck crashes but in addition to the imposed restriction policies there were other improvements made such as shot abrasion and raised pavement markers, whose safety impact could not be independently evaluated.

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Evaluation of the Traffic Safety Benefits of a Lower Speed Limit and Restriction of Trucks to Use of Right Lane Only on I-10 Over the Atchafalaya Basin

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ABSTRACT

To improve traffic operation and safety, several states have implemented truck lane restriction and differential speed limit policies on freeways. In response to an 11-vehicle crash in September 2003, the Louisiana State Department of Transportation and Development (LADOTD) introduced such operational policies on the 18-mile elevated section of Interstate 10 over the Atchafalaya Basin, where trucks were restricted to the right lane and their speed limit was reduced to 55 mph. The speed limit for all other types of vehicles was also reduced to 60 mph. The primary objectives of this research study were to examine the traffic characteristics and truck compliance behavior to the newly implemented policies as well as evaluate the overall safety impact of such policies. Additionally, two opinion surveys were conducted to determine the truck drivers' perception and opinions with respect to these policies. Traffic data were collected and analyzed for four different sites along the freeway corridor using multiple linear regression, pairwise comparison, and statistical two-sample T-tests. The basic statistical analysis showed that the speed in the left lane was much higher than it was in the right lane as a result of the imposed differential speed limit. The results also showed more trucks in the right lane than in the left lane, with a compliance rate in the range of 60 percent to 80 percent most of the time. Further statistical analysis showed that the truck speeds were generally lower than the rest of the vehicles because of their reduced speed limit. For mixed traffic composition, truck speeds were significantly higher than 55 mph, but lower than 60 mph on the right lanes. The truck speeds, however, exceeded 60 mph in the left lane. Thus, trucks generally violated both lane restriction and speed limit. However, it should be noted that truckers were informed through the local trucking association that they were permitted to overtake in the left lane. Thus, their presence in the left lane and their increased speed may be at least partially due to the overtaking maneuver. The results from both surveys were consistent and showed that the truckers were not in favor of the restrictions and did not perceive that significant safety benefits would be gained from such restrictions. In fact, several responses indicated that it would be safer to have uniform speed limits and freedom to select a travel lane. The crash data analysis clearly showed a reduction in the number of crashes, but in addition to the imposed restriction policies there were other improvements made such as shot abrasion and raised pavement markers, whose safety impact could not be independently evaluated.

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IMPLEMENTATION STATEMENT

This research project addressed the operational and safety impact of two restriction policies along the 18-mile elevated section of I-10 over the Atchafalaya Basin. The first restriction is imposed on trucks to use the right lane only, while the second restriction reduces their speed limit to 55 mph. The main objective of the study was to evaluate the effectiveness of such policies and determine if the anticipated safety benefits were gained. The results of the research showed that trucks were relatively compliant to both restriction policies and that safety improvement was observed although the source of the improvement could not be traced to the lane and speed limit restriction policies because several other improvements to the road section were made during the analysis period. The research results are not implementable in terms of whether the currently imposed policies should be kept in place or not.

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INTRODUCTION

On November 28, 1995, the National Maximum Speed Limit (NMSL), which regulated speed limits on public highways in the United States, was repealed. With that repeal, authority was returned to the individual states to set their own speed limits. In an attempt to identify the most appropriate speed limit for Louisiana, the Louisiana Senate requested the LADOTD in Senate Concurrent Resolution Number 4 of 1996 to investigate this issue. LADOTD recommended that the statutory speed limit on all controlled access facilities in the state be raised to 70 miles per hour except where engineering studies determined that the lower speed limits were warranted on individual sections of the system. Other speed limits were recommended for divided highway and two-lane roads.

In August 1998, a series of vehicle crashes involving four fatalities and 32 injuries occurred on the elevated section of I-10 over the Atchafalaya Basin. The then governor of Louisiana requested the secretary of LADOTD to immediately impose a 60-mph speed limit on that section of I-10. At the same time, the secretary of LADOTD formed a committee to develop recommendations on how to improve safety on all elevated sections of freeways in the state of Louisiana. The committee made its recommendations in the *Elevated Interstate Crash Report* in January 1999. Many of the committee recommendations in that report were subsequently implemented.

In September 2003, an 11-vehicle crash on I-10 over the Atchafalaya Basin was caused by a truck failing to notice stationary traffic ahead. Five fatalities resulted from the crash. LADOTD updated its study of this elevated section of I-10 and on their recommendation; it was decided to immediately limit trucks to the right lane of traffic (see Figure 1) and to reduce their speed limit to 55 mph on the elevated section of I-10 over the Atchafalaya Basin. The speed limit for cars was retained at 60 mph (see Figure 2). This was ordered by the chief engineer on August 29, 2003. At the time this research study was initiated, no research study had been conducted to assess the safety implications of the newly implemented policies (reduced speed limit and truck lane restriction) on the Atchafalaya Basin. Although similar policies were implemented in other states such as Texas, the roadway segments on which the policies were implemented had more than two lanes in one direction. The preliminary literature review showed that, although tested, truck lane restriction and differential speed limits had not been implemented before on segments with two lanes in each direction. The Atchafalaya segment of I-10 in Louisiana has two lanes in each direction and operates with both differential speed limits (55 mph for trucks and 60 mph for cars) and truck lane restriction (right lane only).

Figure 1
Right lane restriction for trucks

Figure 2
Differential speed limit for trucks

Roadways are designed to facilitate the movement of passengers and cargoes efficiently, comfortably, economically, and above all, safely. It is the principal goal of the traffic engineer to provide a safe driving environment for highway traffic. As a result of the increasing number of annual vehicle-miles traveled, road users place an increasing demand on highway safety. An important characteristic of highway traffic is the composition of different types of vehicles, including passenger cars, buses, and trucks, etc., that possess different operating characteristics. More specifically, trucks play a significant role in highway safety and operation, since they surpass passenger cars in size and weight. Truck-related fatalities account for a considerable proportion of the total highway fatalities every year, especially when the volume of truck traffic, as well as the physical dimensions of trucks, has been on the rise lately.

To mitigate the impact of truck traffic and improve roadway safety, some states (e.g., Texas) have resorted to policies that restrict trucks in terms of lane use and speed limit. In Louisiana, such policies were implemented along the Atchafalaya Basin section of I-10 in order to make the necessary safety improvements. A research study was initiated by LADOTD to assess the safety impact and to evaluate the driving and compliance behavior of traffic along the study section. Based on the results of this research study, LADOTD is seeking recommendations on the performance and effectiveness of the newly implemented policies.

Literature Review

Even though the roadways are designed to facilitate movement of many different types of vehicles including passenger cars, buses, trucks etc., the impact of all these different vehicle types is not uniform, therefore creating problems in highway safety and operations. In order to reduce the impacts of truck traffic on freeways, two policies are commonly implemented in practice: (1) truck restriction to a certain lane or lanes and (2) reduction of truck speed limits or use of differential speed limits (DSL). There have been more than two decades of research studies conducted in the area of truck safety and operations, most of which were focused on the evaluation of effectiveness of the above-mentioned two policies. During the course of this research project, a comprehensive review was conducted on the current practice of truck lane use restrictions and speed limit differentials as well as past studies that investigated the impact of lane use restrictions, speed differentials, speed limit changes, and techniques to improve safety on elevated highways. This section summarizes the research studies that were published in open literature and their main findings.

Truck Lane Restriction

A truck-lane restriction strategy is implemented to restrict trucks to a certain lane or lanes with the purpose of minimizing the interaction between trucks and smaller vehicles. Since the traffic and highway geometric conditions are different, there have been several possible design alternatives for truck-lane restriction. Researchers collected field data and/or simulated the traffic operation on the road to investigate the impacts of lane restrictions.

A common implemented approach to help reduce the impacts of truck traffic on freeways is to restrict trucks to a certain lane or lanes with the purpose of minimizing the interaction between trucks and smaller vehicles and compensating for their differences in operational characteristics. While the potential benefits of truck-lane restriction are safety and operations, only a limited number of safety related studies exist in the literature. Although there have been no studies identified that specifically address elevated roadways safety issues (the main objective of the RFP), there are several research studies that analyzed efficiency of lane restriction and speed limits in other confined roadway conditions (i.e., overpasses, long bridges, supra-elevated ramps).

Stokes and McCasland (1986) published an article, discussing the findings of a study on the safety and operational influences of truck restriction and regulatory practices in Houston, San Antonio, and Dallas. The six practices included lane restrictions, time-of-day restrictions, speed restrictions, route restrictions, driver licensing and certification programs, and increased enforcement of existing regulations.

Truck accidents, of which the locations were reported, occurred one third of the time in the middle lane(s). This result conformed to the observation that trucks use the middle lane(s) most of the time. Approximately 37 percent of the truck-related accidents occurred in the outside lane, while around 56 percent happened in either the outside lane or on ramp and shoulder areas of the highway. These high crash percentages imply that restricting trucks to the outside lanes was not an appropriate strategy to follow on Texas highways.

In addition, there were frequent freeway-to-freeway interchanges and lane drops on Houston, San Antonio, and Dallas freeways. Employing inside or outside lane restriction would require transition areas before and after lane drops, so that trucks could have time to shift to the other lanes in the vicinity of lane drops. The requirement of the transition areas would increase the enforcement problems related to the lane restrictions. Reduced visibility of the traffic signs, which were located above the right lane most of the time, to motorists, and the concentrated load on the right lane pavement are the other issues associated with restricting trucks to the outside lane.

On the other hand, the speed data for Houston freeways showed that truck and non-truck-vehicle speeds were not significantly different. Another finding was that most of the accidents occurred at off-peak hours. Stokes and McCasland (1986) stated that reducing the speed limit for all vehicles could decrease the total accidents, as well as the truck accidents; however the effects of lowering speed limit for trucks only were disputable. Although enforcement could not be categorized as an action of positive road safety value, increased enforcement of existing speed limits seemed to propose road safety benefits.

The study found out that none of the regulations and restrictions were evident to contribute positively on safety and operations on Texas freeways in the short term. In fact, restricting trucks to the right lane would increase the truck-related traffic accidents on some freeways. With the establishment of the 55 mph speed limit, differential speed limits for passenger cars and trucks might reduce conflicts on urban freeways operating at or near the capacity.

Zavoina et al. (1991) conducted a study to evaluate the operations of truck restrictions on I-20 near Fort Worth, Texas. The restrictions on the specified Interstate section were prohibiting trucks from traveling in the left lane on a three-lane section. The authors analyzed vehicle distributions according to classification, vehicle speeds, and time gaps between vehicles in order to evaluate the operational effectiveness of the left-lane restriction. It is concluded that although the directional distribution of trucks changed significantly due to the imposed restriction, no effects have been identified that could be attributed to the truck restriction in the directional distribution of cars, speed of either cars or trucks, or time headways between vehicles.

Koehne et al. (1996) conducted a study to examine the effects of truck lane restrictions on the safety, efficiency, and pavement of the highway as well as the economic effects on the trucking industry. Three test sites were chosen, two being on I-5 in the state of Washington and one on State Route (SR) 520 in Seattle. The restrictions were one directional, on the uphill grade.

The analysis involved three stages. In the first stage, the in-depth analysis detailed the effects of the lane restrictions. The second step discovered if the results of the in-depth analysis were applicable to other areas in the Puget Sound Region, and the third step required conducting a survey to take the opinions of the truckers, motorists, industry, and the enforcement officials about the lane restrictions.

Results indicated that the lane restrictions did not have a direct impact on highway operations, and restricting trucks from the leftmost lane might increase truck-related accidents because the majority of accidents were caused by changing lanes to the right. The implementation of lane restrictions would cause a $1,155 annual loss to the industry. Pavement life, on the other hand, would not be affected significantly because the truck traffic volumes on the left-most lane were small. However, further implementation of truck lane restrictions in the Puget Sound Region was not recommended due to the unsatisfactory safety, efficiency, pavement deterioration rate, economical benefits, inconsistency among the sites, and the opposition to the lane restrictions from the motor carrier industry.

The report of Hoel and Peek (1999) investigated the impacts of lane restriction on traffic flow elements such as density, lane changing, and speed variance. Three sites were chosen on I-81 in Virginia. The data was collected for four initial volume distributions on 0 percent, 2 percent, and 4 percent grades at these sites. FRESIM simulation model was used to approximate traffic flow elements. Two different restriction strategies were tested: restricting trucks from the left lane and restricting trucks from the right lane. The results indicated decline in the density and the frequency of lane changes and incline in speed differentials when trucks were restricted from using the left lane on steep grades.

On the other hand, there was an increase in the frequency of lane changing maneuvers when trucks were restricted from using the right lane. Another important finding was that the impacts of truck lane restrictions were dependent on the site characteristics. Based on these findings, Hoel and Peek (1999) recommended restricting trucks from using the left lane on grades 4 percent or steeper. They advised that trucks should not be restricted from the right lane. The findings of this study did not support rescinding the truck lane restriction policy in Virginia.

Mussa and Price (2004) aimed at examining the safety and operations on I-75 in Florida, where a median-lane restriction for trucks takes place. Their particular objective was to find out the influence of the restriction on truck operating speed and travel time throughout the day. To accomplish this, they analyzed the change in speeds and travel times on the corridor both for the daytime restriction only and the 24-hour restriction. In addition, a crash analysis was conducted. Both field data and simulation were used. CORSIM Version 5 simulated the traffic operations on the road. The results revealed that the current policy of restricting trucks from the median-lane provided safety and efficient operation and should be left in place. Repeal of this policy would not reduce travel times or delays. The study showed that improper lane changing is one of the primary causes for traffic accidents, and if the trucks were to be allowed to use all the lanes, the frequency of lane changes would increase.

Borchardt (2002) discussed a Houston demonstration project on truck lane restrictions. Minimum 6-mile-long, having at least 4 percent truck volume and a radial section within the Houston city limits as being the criteria for the site selection, an 8-mile section on I-10 East Freeway was chosen as the project site. The truck volume data collected throughout 36-weeks of truck restriction was compared with the truck volume data compiled before the restriction. The results indicated that restriction reduced traffic accidents by 68 percent. The restriction did not create any changes in freeway operations, travel time, frequency of lane changes, or traffic patterns. About 90 percent of the surveyed automobile drivers supported the implementation of truck lane restriction policy.

The article published by the Texas Transportation Institute (2002) compared pros and cons of implementing truck lane restrictions. Although maximizing efficiency and success of designated lanes was a difficult and complex process, the article pointed out that designated lanes were believed to be the best approach for moving traffic more efficiently and improving safety on highways that were frequently used by 18-wheelers.

Kuhn et al. (2002) studied the current state of the practice in managing lanes. The report mentioned a survey that investigated the experiences of the states in lane restrictions upon the request of Federal Highway Administration in 1986. According to the survey results, lane restrictions were being used in 26 states. While 14 states implemented the restrictions to improve highway operations, 8 sought reduction in accidents, 7 considered benefits in pavement structures, and 7 required restrictions in construction zones. The number of states that reported combinations of reasons was 20.

Models were developed by Gan and Jo (2003) to find out the strategy for truck lane restrictions that offered the most efficient operations on highways. The performance criteria included average speed, throughput, speed differentials, and lane changes. Number of lanes, interchange density, free-flow speeds, volumes, truck percentages, and ramp volumes were given. The simulation results showed that average speed increased when the interchange density, truck volume, and ramp volume were low. Throughput increased when the number of restricted lanes increased. Low number of restricted lanes (e.g., one out of three) brought higher capacity than the non-restriction case for maximum truck percentage of 25 percent. The authors conclude that, in general, when the section with restricted lanes is not under heavy weaving and lane changing conditions, like sections with densely spaced interchanges, having restricted truck lanes is beneficial operational wise.

On the other hand, there was considerable speed differential between restricted and non-restricted lane groups, and the magnitude increased proportionally with the increase in the number of interchanges, ramp volumes, truck percentages, and free-flow speed. Another important point was that truck lane restrictions decreased the frequency of traffic accidents by separating the slower vehicles from the faster ones and reducing the frequency of lane changes. The appropriate number of lanes to be restricted was stated as one lane on three-, four-, five-lane highways, and two lanes on four- and five-lane highways if the interchange density was not high and the truck percentage was at or below the average.

Douglas et al. (2003) compiled the current strategies in practice to manage the truck traffic on U.S. highways. Their report emphasized the rapid increase in the truck volume on roads compared to the increase in population, overall vehicle travel, and highway system capacity. It also pointed to the threat this rapid increase poses on safety, operations, environment, economic development, and public wellbeing. Douglas et al. surveyed 28 state departments of transportation and 8 metropolitan planning organizations that started projects and implemented strategies to manage the increasing truck traffic and the challenges it created. Lane restriction, which was considered to be an operational strategy, came out to be one of the most frequent strategies to be executed, along with improved pavement, climbing lanes, and weigh-in-motion.

According to the respondents, safety was the primary and congestion was the secondary concern for adopting lane restrictions for trucks and improved incident management. Time-of-day restrictions primarily took in hand congestion, secondarily safety, while the concentration of truck restrictions on roads was primarily on safety and secondarily on infrastructure deterioration and congestion. Although lane restriction was a popular strategy nationwide, two states considered but then rejected implementing lane restriction policies due to the insufficient benefits and difficulty of implementation. The same was true for the time-of-day restrictions though it was not as commonly practiced as lane restriction. These cases pointed out that not all strategies are suitable to all situations, and significance should be given to public opinion, project cost, likely benefits, and ease of implementation.

In his article, Zeitz (2003) examined South Carolina’s strategy to reduce traffic accidents under limited resources. After continuing traffic accidents on I-85, which was a road frequently used by trucks, South Carolina Department of Transportation (SCDOT) executed truck lane restrictions temporarily for one year on sites that constituted high risk for crashes. Targeted enforcement was applied both for lane violations and aggressive driving violations. In the outcome, the truck related accident rates decreased by 78 percent. This result facilitated FHWA, SCDOT, the South Carolina Department of Public Safety, and the South Carolina Truckers Association to reach a consensus that restricting trucks from the leftmost lane on three-lane sections would propose safety and operational benefits. As a result, the length of the state’s highways that involved truck lane restrictions increased to 106 miles. Although truck crashes showed a slight rise after the truck lane restrictions were fully put into practice in 2001, the fatalities decreased.

Fontaine (2003) discussed the findings of a study on the engineering and technology solutions to enhancing large truck safety in Virginia. The Virginia Department of Transportation (VDOT) employees were surveyed to find out the engineering and technology actions that were being taken in Virginia. Survey respondents mentioned the effectiveness of truck lane restrictions on truck climbing lanes or steep uphill three-lane directional sections, and the improvement in the traffic flow and safety on U.S. 29 through the Madison Heights area of Amherst County as a result of restricting trucks to the right lane.

On the contrary to the positive opinions of the survey interviewees and the results of many other studies conducted around the nation on the benefits of truck lane restrictions, the data from the study of lane restrictions on the Beltway and I-95 demonstrated an increase in the crash rates. Fontaine stated that the benefits of truck lane restriction strategy were still not evident due to the limited data on this subject. Likewise, it was not known whether differential or uniform speed limit between cars and trucks provided safety. The report underlined the necessity of further research in these two areas.

Harwood et al. (2003), in their work, entitled "Highway/Heavy Vehicle Interaction: A Synthesis of Safety Practice," synthesized the knowledge about the safety interaction of trucks and buses with the highway elements and then analyzed the assembled information. They also determined what could be done to improve the heavy vehicle safety on roadways. The results of the study revealed that the fraction of the highway agencies that used or were considering the use of differential speed limits was 2/5; however, the safety benefits of differential speed limits was not proven. In fact, the speed variance between the passenger vehicles and heavy vehicles might cause more traffic accidents. Truck lane restrictions, as well, did not demonstrate any safety benefits nor did it show any negative impact on highway safety in most of the evaluations. On the contrary, a recent test in Houston, which lasted eight months, reported a safety benefit of restricting trucks from using the left lane. Harwood et al. recommended conducting more research on differential speed limits and truck lane restrictions in order to find out their impacts on highway safety.

A simulation study by Cate and Urbanik (2003) showed the effect of prohibiting trucks in the left lane on three-lane highways. The VISSIM traffic simulation model was used to test different scenarios and analyze the results. Truck lane restriction caused a slight increase in the vehicle density and level of service on flat grades. However, as uphill grades approached 4 percent, the impact became more significant. Similarly, the average travel time was affected slightly on flat grades, although it reduced considerably on steep (4 percent) uphills.

The study also showed that speed differential between cars and trucks was less than 1 mph on flat sections, while it climbed up to 9.9 mph on steeper sections of the highway. Another variable tested was the occurrence of lane changing. The reduction in lane changes by trucks surpassed that of cars on flat sections, but they were almost same on uphill sections. The safety problem generated from the speed differential between cars and trucks was offset by the safety benefits of reduced lane changing.

Overall, prohibiting trucks from using the leftmost lane on highways with three or more lanes in the same direction had no negative effect on highway safety or operating efficiency.

Cate et al. (2004) specified the impacts of lane use restrictions employed for large trucks on Tennessee's highways, and set guidelines for implementing these restrictions after a thorough observation of lane use restriction practices in other southeastern states. Tests showed that even with minimal use of signage and enforcement, the truck percentage in the left lane decreased significantly after the lane use restriction was put into practice. The study recommended that truck lane use restrictions be applied on freeways with at least three lanes in one direction. Also, restricting trucks to a single lane was not advised, because the barrier effect and the accelerated pavement wear it might cause would prevail over the potential benefits of the restriction.

Using pavement markings to indicate the truck lane restrictions, placing warning signs on the center median, overhead structures, or on the right shoulder to remind the drivers of the restriction and to take the attention of noncompliant drivers one mile before the restriction area were considered essential. Another recommendation was that truck lane restrictions be temporarily lifted if a work zone was located at the site of the restriction, due to the safety concerns.

Although truck speeds increased in a few observations, the study showed a slight decrease in its measure. Truck speeds being higher than the posted speed limit could be argued for its safety benefits. Overall, lane use restrictions provided few tangible operational and safety benefits and produced the insight of enhanced safety and comfort in the majority of the motorists. After meeting all other requirements, the public insight would help the widespread practice of the truck lane restrictions in Tennessee.

A study, by Knipling et al. (2004), stated that the purpose for implementing lane restrictions had more to do with improving efficiency of a freeway rather than enhancing safety. In fact, it was mentioned that lane restrictions, in some cases, created unfavorable effects on highway safety. Knipling et al. pointed out that the truck lane use restriction was appropriate for interstates with at least three lanes in one direction. Issues involved with implementing a lane use restriction strategy were detailed in the report. Speed differentials and lane changes were considered substitutes for safety, and some of the factors causing the accidents.

To ensure the safety benefits of potential lane restrictions, it was recommended that pilot studies be implemented. Most of the time, lane use restrictions required the authorization of the legislation, but the legislation sometimes authorized state DOTs and local agencies to apply the lane use restrictions on facilities under their control. All the stakeholders, primarily law enforcement officials and organizations that represent the commercial transporters using heavy trucks, should be included in the implementation stage of the lane use restriction. Being aware of the views and perceptions of the truck operators were essential to the success of the lane use restriction program.

Hanscom (1990) compared truck lane restriction on a three-lane road with truck lane restriction on a two-lane road. The three-lane section is located in an urban area near Chicago and the trucks were prohibited to travel in the most left lane, while the two-lane site is a rural interstate section in Wisconsin with pavement deterioration, which prevents the trucks from traveling in the right lane. It is concluded that beneficial traffic flow effects (e.g., reduced congestion) are associated with the left-lane truck restrictions on three-lane roadways. On the other hand, the author's findings on the two-lane restrictions site include high violation rates and slowing of impeded vehicles, which raise safety issues.

A recent study investigated the impact of large trucks on interstate highway safety in Kentucky by Agent and Pigman in 2002. The report summarizes a set of countermeasures to address truck crashes on interstate highways based on the analyzed crash data, discussions with truck industry representatives, and reviews of state-of-the-art procedures and technologies in the area of traffic safety. Namely they were grouped in three categories: (a) the road environment, (b) truck, and (c) driver. Among these the authors suggested that truck lane restriction should be used on sections with three lanes or more. Also they suggest that specific ITS technology needs to be implemented (i.e. real-time traffic congestion/information system, automated screening of trucks to reduce congestion at weigh stations, speed monitoring equipment and truck speed advisory systems to warn drivers about low design speeds, etc.).

Differential Speed Limit (DSL)

Differential speed limit is to set lower speed limits for trucks, compensating for their differences in operational characteristics. Fewer literatures were available in DSL compared with studies in truck-lane restrictions. Most concern of the DSL study was the impact of speed variance on traffic accident.

A survey conducted by Sunbelt Research Corporation (1980) questioned the Louisiana drivers about the 55 mph speed limit and other highway safety issues. The survey results showed that most of the motorists drove faster than the speed limit on interstate highways. The respondents who were not in favor of the speed limit change formed two thirds of the interviewees. The majority of the drivers who often exceeded the speed limit were a part of this fraction of interviewees. Half of those who thought the speed limit should change stated that 60 mph was a reasonable speed limit. According to most of the respondents, the reasons for speeding were being in a hurry, enjoying the sensation of speed, habit, to save time, and roads and cars being designed for higher speeds.

Those who thought speed limit enforcement was performed by the state police formed half of the interviewees; those who believed it was not formed one third, and the remaining fourteen supposed it was unpredictable. Majority saw enforcement as an essential factor for higher compliance rates, while only one fifth claimed education and advertising would be the solutions.

A report by Lave and Elias (1994) undertook an analysis of the statewide effects of the maximum speed limit change from 55 mph to 65 mph on rural interstate highways in 1987. The authors collected data from every state and measured the changes in fatality rates. They adopted the Garber and Graham model in the regression analysis stage. This model held constant the effects of long term trend, driving exposure, seat belt laws, and economic factors. As a result, the state-by-state fatality rates declined by 3.4 percent to 5.1 percent. This outcome was probably because of the driver's selection of safer roads, the highway patrol resource transfer to activities that have more safety payoff or the reduction in the speed variance among vehicles on the interstates.

Milliken et al. (1998) reviewed the current practice for setting and enforcing speed limits on all roads in the United States and guided the state and local officials on a suitable technique to set and enforce speed limits. Milliken et al. stated that there was a tradeoff between safety, travel efficiency, and rationality of enforcement when speed limits were being set. Most of the time, safety became the determining factor because severity of traffic accidents depended on the pre-crash speed of the vehicle. Higher speed limits caused increases in the speed dispersion. The higher the speed dispersion on rural interstates, the more crash fatalities there were. The minimum speed dispersion was obtained when there was 5-10 mph difference between the road design speed and the posted speed.

Another factor that triggered crashes was the great difference in the speeds of the vehicles on a portion of the highway. This was seen in the area around interchanges. In fact, the high traffic volume near interchanges on urban interstates increased crash rates, which indicated the role of traffic density in the occurrence of traffic accidents. Milliken et al. noted that enforcement and creative engineering measures were necessary for desired driver compliance with the posted speed limits.

Wilmot and Khanal (1999) reviewed the effects of speed limits on vehicle speed and safety on roadways. They stated that there was no proof of the positive impact of differential speed limits on highway safety. In addition, the difficulty of differentiating day and night at dawn or dusk was the shortcoming of employing differential speed limits based on the time of day. Besides, applying differential speed limits at urban boundaries created a problem: renewing the start and end of differential speed limits when urban areas grew rapidly. Additionally, using differential speed limits required extra signs and supplementary enforcement, bringing us to the issue of money.

Considering these shortcomings, instead of applying differential speed limits to the entire network, more appropriate actions, where necessary, are implemented: speed zoning at sites where lower speed was warranted and situating warning or regulatory signs dedicated to trucks in order to differentially control their speeds.

A study was conducted by Rajbhandari and Daniel (2002), detailing the effects of trucks on highway safety after the speed limit was increased to 65 mph for passenger cars and trucks on New Jersey freeways. The results of this study showed that trucks had an impact on the number of accidents after the speed limit changed. The frequency of accidents at nighttime increased, and the frequency of rear-end collisions decreased while sideswipe collisions rose.

A report, by Garber et al. (2003), judged the safety effects of differential speed limits on rural interstate highways against those of uniform speed limits. It was found that changing from a uniform speed limit to a differential speed limit or vice versa had no impact on the mean speed and speed variance of vehicles on highways. Also, crash rates had no association with the type of speed limit chosen.

Monsere et al. (2004) evaluated the effects of a proposed maximum speed limit change to 65 mph for trucks and 70 mph for passenger vehicles on Oregon's interstate highways. The maximum posted speed was 55 mph for trucks and 65 mph for passenger vehicles at the time of the study. The report examined the influences of speed change on motor-vehicle accidents, enforcement, health, economy, and the environment. The results indicated negative effect on all but travel time and some economic development benefits.

Kweon et al. (2005), in his report, estimated the total safety effects of speed limit changes on high-speed roadways by using traffic detector data and Highway Safety Information System data from 1993 to 1996. The study used a sequential modeling approach in which average speed and speed variance models were first estimated based on the design, use, and speed limit information; crash counts were estimated based on the speed estimates, design, and use variables. About 63,937 homogeneous highway segments along Washington State's 7 interstates and 143 state highways provided the data for 4 years. Results indicated lower nonfatal crash rates up to 55 mph speed limit. On the other hand, fatality rates were unresponsive to speed limit changes.

Ivey et al. (1977) investigated alternative techniques to prevent traffic accidents at narrow bridges. The results of his report identified several actions. Where there was an obvious sight distance problem, it was recommended that roadways be realigned. Replacing bridge rail with smooth rail would facilitate redirecting the vehicle. If there was a problem of grade continuity, approach grades should be adjusted. Installing approach guardrail, placing edge lines and transition markers, mounting narrow bridge and advisory signs, adding signs and removing centerline strips on one-lane bridges, redirecting commercial vehicles, and reducing the disturbance of lights and roadside obstructions were other considerations in improving narrow bridge safety.

A study was conducted by Makino (1996) to develop an incident detection system. This system could detect tunnel accidents and traffic jams by employing image processing technology and from the delivery of video signals by Closed Circuit Television (CCTV) cameras. Distinguishing between real incidents and normal environment changes was made possible by a proprietary directional-temporal plane transform (DTT). Fuzzy logic algorithm facilitated the coordination of image processing between tunnel cameras and deduced the presence of accidents in ways unobtainable in direct approaches to image processing.

Mayers (2001) studied tunnel accident detection using digital video analysis. This method was reported to improve tunnel safety. Besides traffic flow, traffic density and speed data, the following hazards could be detected by video imaging technique: fire, smoke, stopped vehicles, and ghost drivers. Online analysis of the video data could help to intervene immediately after the occurrence of incidents. Storage of recorded data, which can be used in successive reconstruction of incidents, was another advantage of digital video analysis.

Summary of the Literature Review

A summary of the key findings from the literature review on truck lane restrictions and DSL is listed below:

1. A number of studies have been conducted on truck lane restrictions and DSL at various sites and/or simulation conditions. The conclusions drawn from those studies are limited to conditions associated with each individual study;
2. Contradictory conclusions were found on the safety benefits and effectiveness for both truck lane restrictions and DSL in literature;
3. No study has been conducted on the effectiveness of implementing both trucks-lane restriction and DSL on segments with two lanes in each direction as Atchafalaya segment of I-10;
4. Studies on truck lane restrictions and DSL were conducted on flat and uphill grade segments, but not on elevated segments like the Atchafalaya segment.

Given the findings of the literature review, it is necessary to perform an in-depth study to investigate the performance and effectiveness of the implementation of truck lane restrictions and DSL on the Atchafalaya segment of I-10 in Louisiana.

OBJECTIVES

The primary goal of this research study was to assess the operational and safety impact of the newly implemented policies (differential speed limit and truck lane restriction) on the Atchafalaya Basin segment of I-10. The study was limited to the designated two-lane rural freeway segment of I-10 where such restriction policies are in effect. The study investigated and quantified the effectiveness of such policies by monitoring the safety and operational conditions of traffic on the study segment. More specifically, the research objectives of this study were to:

1. Monitor and study the traffic behavior and compliance rates for both cars and trucks on the study segment.
2. Conduct detailed crash analysis for the study segment before and after the implementation of such policies as well as make comparative analysis with other similarly elevated sites.
3. Conduct an opinion survey on the newly implemented policies and the perception of the trucking industry.
4. Make final recommendations to LADOTD on the operational effectiveness and safety impact of existing policies.

SCOPE

The scope of this research study was limited to the Atchafalaya Basin section of I-10, which is one of the elevated sections of the freeway where the new policies of the truck lane restriction and speed limit differentials were implemented. For the purpose of this study, traffic data were collected to study the characteristics of traffic flow on that section. The characterization included analysis of traffic flow under different vehicle composition and traffic conditions. Safety analysis also required a collection of crash data before and after the implementation of the new policies. Figure 3 shows a map of the study segment and its surroundings.

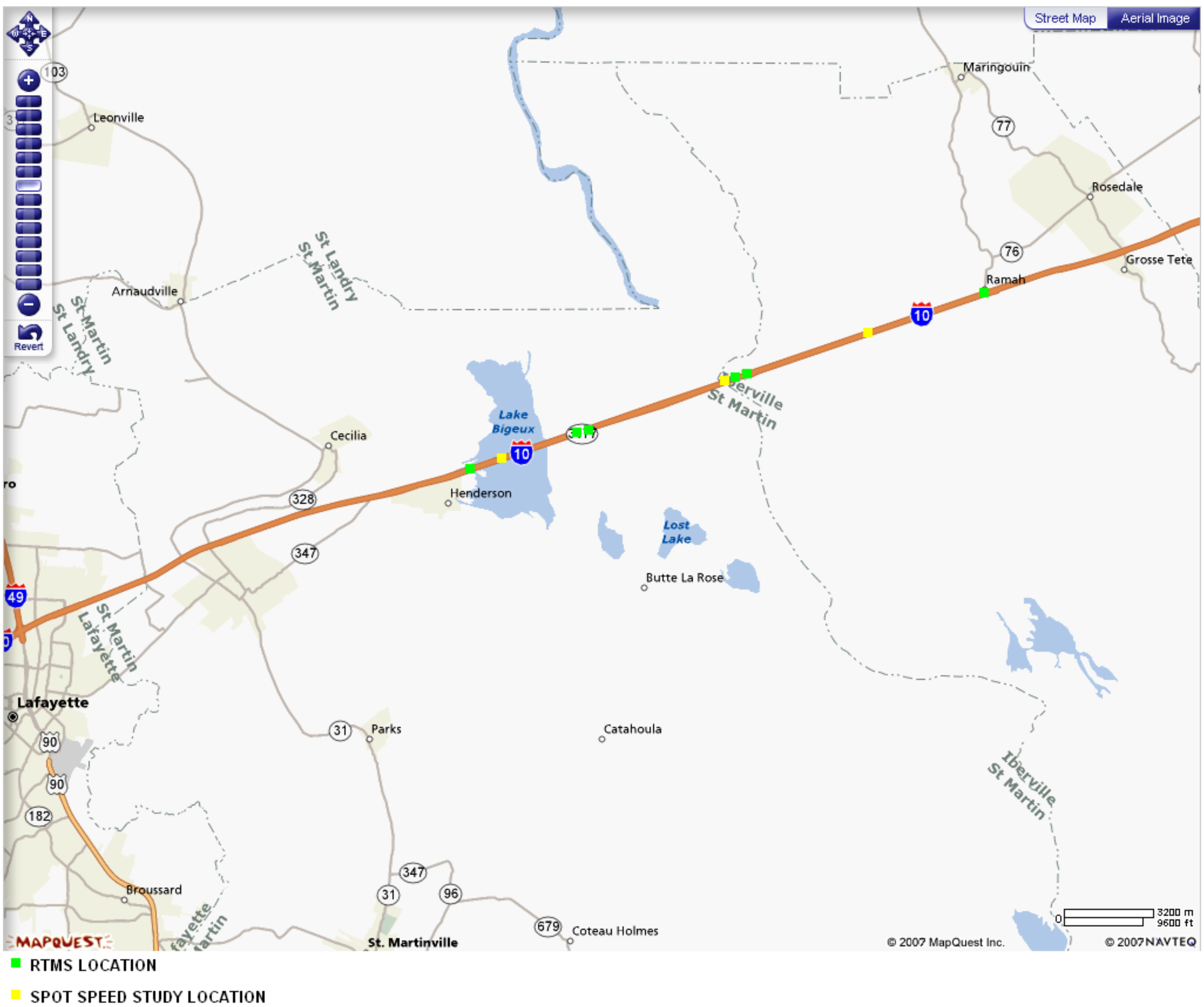


Figure 3
Map of the Atchafalaya Basin study segment

METHODOLOGY

Introduction

One of the primary research objectives of this study was to monitor and examine the traffic behavior and characteristics for both cars and trucks on the study segment. One of the critical characteristics that the study focused on was the compliance rates of both cars and trucks to lane restriction and speed limits. Since the primary goal of the study was to evaluate the safety benefits of the speed limit differential and truck lane restriction implemented in 2003, it was crucial to determine the effectiveness of such policies. This section presents a detailed description of the data collection process and the traffic data equipment used.

Study Section

The study was conducted on the elevated Atchafalaya Swamp section of I-10, shown in Figure 4. The study section runs from milepost 135 (near Ramah) to milepost 117 (near Henderson). The section is nearly 18 miles long and has two lanes in each direction. Along this section, trucks are restricted to the right lane with a speed limit of 55 mph. Cars are free to use both lanes with a speed limit of 60 mph. Traffic data were collected along the study section at four different locations (two in each direction). The traffic data equipment used was the remote traffic microwave sensors (RTMS) currently deployed at various locations throughout the state of Louisiana. Detailed description of RTMS and their use in this project is provided next.

Remote Traffic Microwave Sensors

RTMS is a traffic monitoring device that has been widely adopted by traffic management centers in many states, including Louisiana (e.g., I-10 and I-12). RTMS, manufactured by Electronic Integrated Systems (EIS), Inc. is a low-cost, general-purpose, all-weather traffic sensor that detects presence of vehicles and measures traffic parameters in multiple independent lanes across one direction of travel. It provides volume, occupancy, speed, and vehicle classification information. The coverage area of RTMS may include up to eight discrete user-defined detection zones over a distance up to 200 ft. Output information is provided to existing controllers via contact pairs and to computer systems via a RS-232 serial communications port. Figure 5 shows a snapshot of the RTMS radar device mounted by the roadside. For remote locations with limited access to power sources, RTMS units can be solar powered as shown in Figure 6.

Figure 4
A map of the Atchafalaya section of I-10

Figure 5
A snapshot of a roadside mounted RTMS device

Figure 6
RTMS solar powered remote counting station

RTMS is miniature radar operating in either of two microwave bands, employing the Frequency Modulated Continuous Wave (FMCW) principle. It transmits a low-power microwave signal of constantly varying frequency in a fixed fan-shaped beam. The beam "paints" a long elliptical footprint on the road surface. Any non-background targets will reflect the signal back to the RTMS where the targets are detected and their range measured as shown in Figure 7. The RTMS device is well suited for side-fired operation, as it is the case with the study section of I-10 where no overhead structures are available. It is usually mounted on existing side-of-the-road poles as shown in Figure 8.

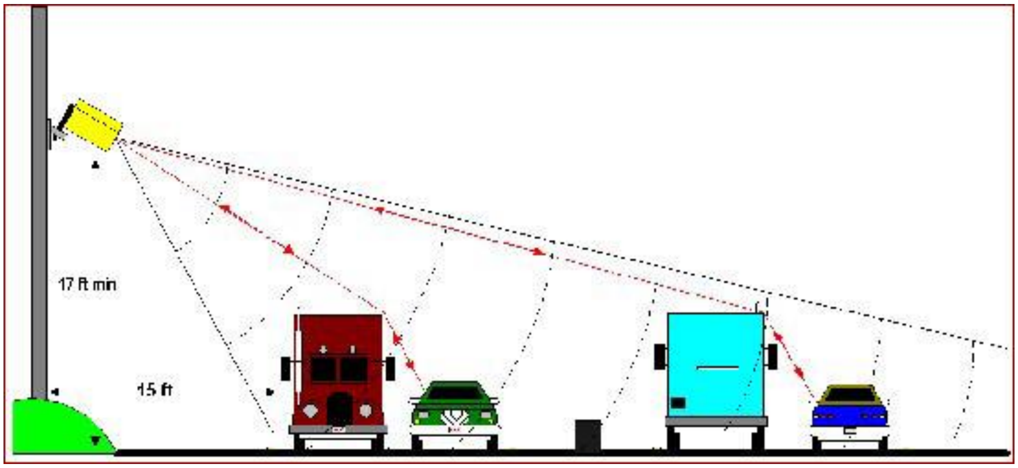


Figure 7
Microwave signal of RTMS and method of vehicle detection

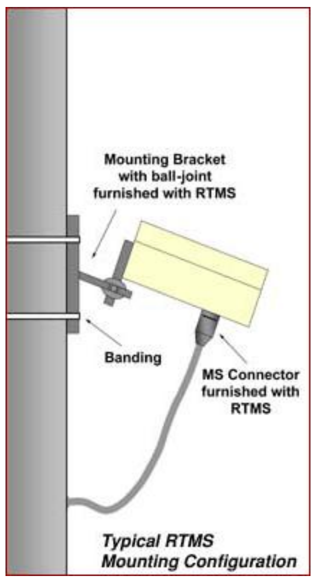


Figure 8
RTMS mounting configurations

The RTMS equipment can also tolerate small amounts of movement or vibration, which may be experienced when it is mounted high enough to allow readings across multiple lanes. The RTMS device may also include a Remote Traffic Counting Package (RTCP), a queue trailer, and RTMS™ Wireless Communications, which is the option pursued by the research team on this project in order to stream the traffic data in real time from the site to Louisiana State University (LSU). The accuracy of RTMS is measured by the errors in each observed parameter and differs by the mounting type (side-fired or overhead). Table 1 shows the measurement level errors by mounting type.

Table 1
RTMS measurement error levels

Parameter	Side fired error	Overhead error
Presence	±5%	±2%
Volume	±5%	±2%
Lane Occupancy	±5%	±2%
Average Speed	±10%	±2%
Per Vehicle Speed	N/A	±2%
Length Classification limits	±10%	±10%
Time event	10ms	10ms
Input Voltage	±2%	±2%

This section presents a summary of the evaluation results for the traffic monitoring devices already installed along the study section of I-10 when the project started. The need for evaluation was initiated from a meeting that was held on March 9, 2007 between representatives of LADOTD, Federal Highway Administration (FHWA), and LSU. The purpose of the evaluation task was to assess the operational status of the currently installed traffic monitoring equipment and the quality of data collected. It was also necessary to examine the capability of the existing devices to stream traffic data in real time via a cluster controller to a remote computer over wireless cellular communication. The evaluation process was completed on March 30, 2007, by Signal Equipment Co. (South), a branch in Louisiana affiliated with EIS.

Evaluation of Existing Traffic Data Collection Devices

The site inspection revealed that the monitoring devices are radar vehicle detectors (RVD) that were originally installed by LADOTD for the purpose of traffic monitoring and speed advisory signs on the Atchafalaya Basin Bridge. There were six field sites where RVDs were installed as shown in Table 2. The six RVDs are also shown in the map depicted in Figure 9.

Table 2
Location of existing RTMS units on the Atchafalaya section of I-10

LOCATION	RVD#	Radio #	Mile Post
I-10 WESTBOUND RAMAH BEGIN BRIDGE	19	1033	135
I-10 WESTBOUND WHISKEY BAY	20	1034	126.4
I-10 WESTBOUND BUTTE LAROSE	21	1035	120.8
I-10 EASTBOUND HENDERSON BEGIN BRIDGE	22	1036	117
I-10 EASTBOUND BUTTE LAROSE	23	1031	122.1
I-10 EASTBOUND WHISKEY BAY	24	1032	128.4

The currently installed RVDs are X-2 models that can collect automobile average speed, vehicle counts, occupancy, and vehicle counts. Communications with each of these sites was established by wireless transceivers to a central point located at the LADOTD Butte La Rose microwave tower. Site testing revealed problems with obtaining information from the RVDs. It was also found that wireless communication was limited to four of the sites listed in Table 2, RVD numbers 20, 21, 22, and 23. The RVD setup software was used for evaluating RVD operation and indicated that RVD number 21 was operating in a satisfactory manner in terms of collecting traffic data. RVD numbers 20, 22, and 23 exhibited signs of malfunction that could be attributed to either RVD operation or wireless communications. Such problems could also be caused by low power stored in the batteries. Generally, the following components at each site were checked for operation and conditions: solar panels, battery, connections, and RVD operation and setup as follows:

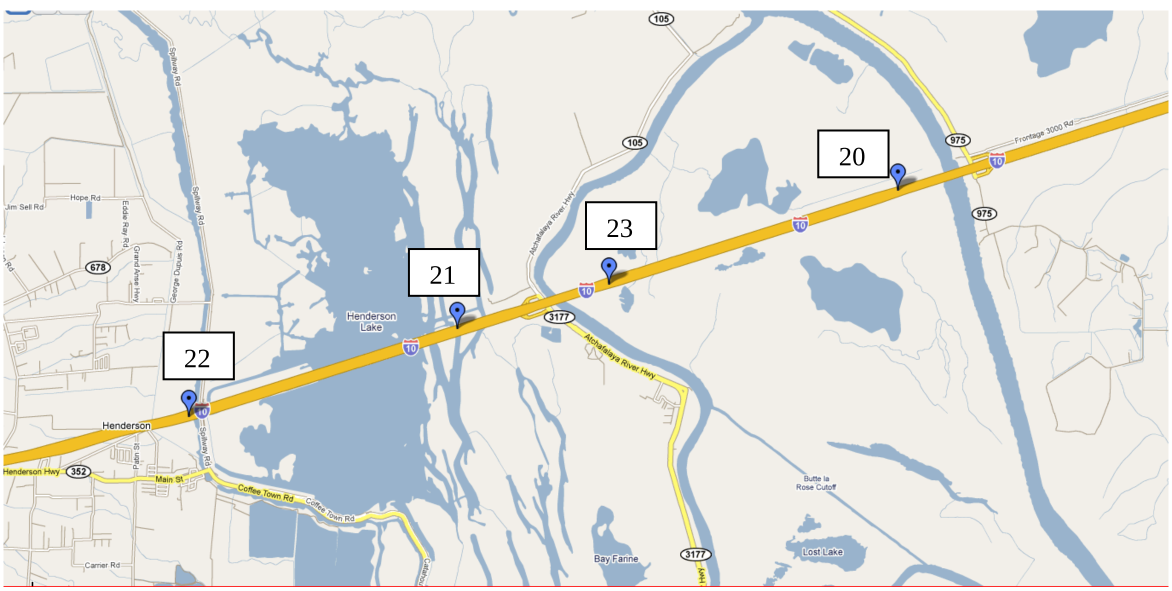


Figure 9
Location of existing RTMS units on the Atchafalaya section of I-10

1. The solar power system and batteries were found to be in excellent condition and operating satisfactorily at all sites. Battery voltages were approximately 13 Volts, and the solar cells were providing approximately 2 amps under cloudy conditions to over 4 amps with full sun. The solar controllers were all functioning satisfactory with the meter indications showing the voltage and amperages mentioned previously. The voltage was checked with a separate volt meter and found to be very close to the reading on the solar controller. It was decided that the power system should continue to function without any problems in the near future.
2. All connections checked were found to be correct and secure; no apparent problem was found.
3. To check the operational status of RVD devices, each RVD was connected to a laptop computer and the RVD setup software was run to perform diagnostic tests.

The operational status of each of the six RVD devices is summarized as follows:

- RVD#19: A communication problem was found between the unit and the laptop computer. This is usually an indication of failure in the internal RS232 of the RVD and that the unit must be serviced by the factory.

- RVD#20: This unit did not detect vehicles, which is usually an indication of failure in the microwave transmitter or sensor. Again, this unit needed to be sent to the factory for service.

- RVD#21: All functions of this unit appear to be operating properly. The unit was setup correctly and traffic on both lanes of traffic was detected. During the evaluation tests, the speed sensor was calibrated to the actual vehicle speeds on the roadway.

- RVD#22: A communication problem was detected between the RVD unit and the laptop computer. The unit needed to be serviced at the factory.

- RVD#23: This unit did not show any signs of malfunctioning. However, only left-lane traffic was detected. This unit needed to be adjusted and setup again to provide accurate traffic data.

- RVD#24: All functions of this unit appeared to be operating properly. Traffic on both lanes was detected. However, speed calibration was not performed since this unit was not communicating with the microwave tower.

Overall the evaluation showed that there were three units functional and three units to be serviced. Four units communicated properly with the microwave tower, two of which were operational and one needed adjustment and further setup for proper lane detection and speed calibration. Therefore, there is only one operational unit of the four relaying data to the microwave tower that could be used to provide accurate traffic data. While the existing communication by wireless transceivers was functional, it was limited to only four of the six units. In consideration of the amount of effort required to repair the defective units and the safety of the maintenance personnel required at each of these sites, a recommendation was made to replace the current RVDs with newer models of RTMS (X-3), which have additional data collection capabilities. Moreover, EIS agreed to provide a free license of WATER software to LSU for acquiring field data from the new RVDs. This software was recently updated to process data from the X-3 models of RVDs. Some of the significant differences between the X-2 and X-3 models of RVD are highlighted next:

1. X-3 models have improved detection when the lanes are close to the unit as it is the case for the Atchafalaya section.
2. X-3 models have improved speed calculation for cars and trucks.
3. In X-3 models the number of vehicle classifications was increased to four types of vehicles with variable lengths.
4. X-3 models have enhanced operational characteristics for obtaining automobile average speed, vehicle counts, occupancy, and additional classifications for long vehicle counts.

Installation and Setup of New Replacement RTMS Units

This section describes the installation and setup procedure for the new X-3 units to replace the existing RVD units 20, 21, 22, and 23. The new RVDs have enhanced operational characteristics for obtaining automobile average speed, vehicle counts, occupancy, and additional classifications for long vehicle counts. Each of the four new units of RVD was installed by LADOTD personnel using LADOTD equipment. Once installed the units were setup for each location to detect two lanes of traffic. Generally, the setup of the units is the same with only small deviation to accommodate the uniqueness for each. A laser vehicle speed detection unit was used to verify the actual speed of the vehicles and to calibrate the speed detection in the RVDs. Four vehicle classifications were setup in each unit for vehicles with lengths of: (1) regular ($L \leq 26$ ft.), (2) midsize (26 ft. $\leq L \leq$ 36 ft.), (3) long (36 ft.$\leq L \leq$ 56 ft.), and (4) extra-long (56 ft. $\leq L \leq$ 76 ft.). Based on the RTMS vehicle classification system, trucks were assumed to belong to the predefined class categories "long" and "extra-long." It should be noted, however, that both categories used to define trucks may also include other types of vehicles whose length falls in the same category, such as recreational vehicles, buses, and vehicles with trailers. Considering the general traffic characteristics of this section, it is believed that the percentage of vehicles misclassified as trucks was much lower than the actual percentage of trucks. A few changes were also made to the radio as shown in Table 3. The location of each of the four units replaced is also depicted in Figure 10 through Figure 13.

Table 3
Location of new RTMS units

Location	Serial Number	LSU ID Number	RVD#	Radio #	Milepost	Zone
I-10, WESTBOUND, WHISKEY BAY (Figure 10) 30°21'44.86"N, 91°38'57.32"W, 22 ft Elev.	9655	659932	20	1034	126.4	1
I-10, WESTBOUND, BUTTE LAROSE (Figure 11) 30°20'18.46"N, 91°44'16.88"W, 16 ft Elev.	9656	659933	21	1035 (replaced by radio #1033)	120.8	2
I-10, EASTBOUND, HENDERSON, BEGIN BRIDGE (Figure 12) 30°19'23.66"N, 91°47'31.72"W, 21 ft Elev.	9657	659934	22	1036	117	3
I-10, EASTBOUND, BUTTE LAROSE (Figure 13) 30°20'46.62"N, 91°42'27.31"W, 20 ft Elev.	9658	659935	23	1031	122.1	4

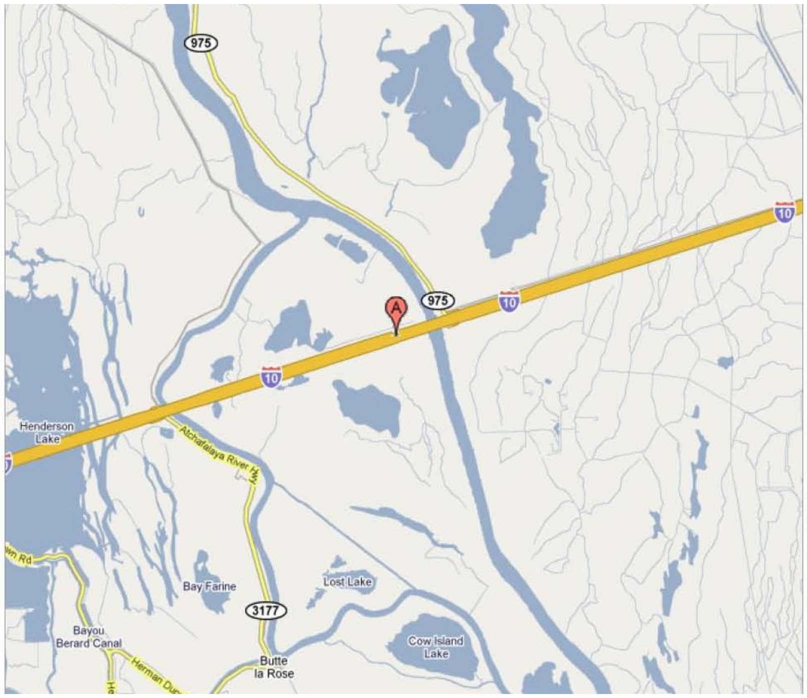


Figure 10
Location of RVD #20 at milepost 126.4 on I-10 westbound

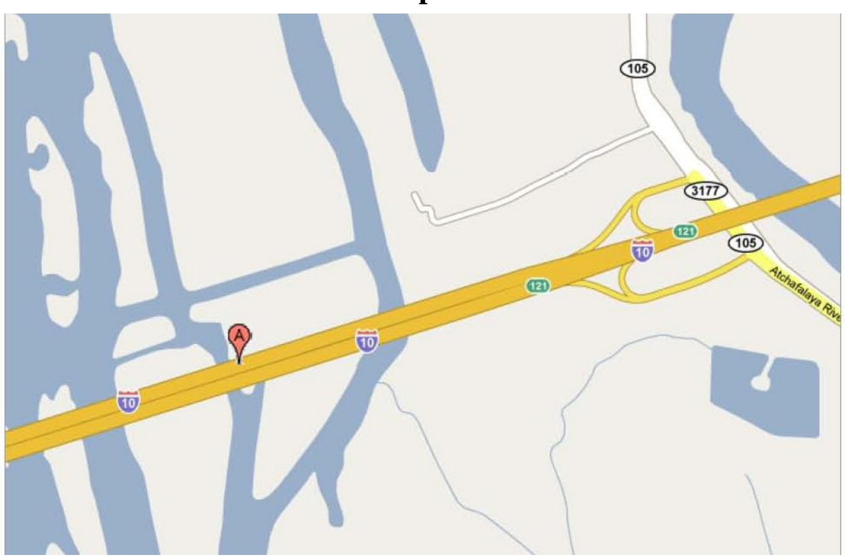


Figure 11
Location of RVD #21 near milepost 120.8 on I-10 westbound

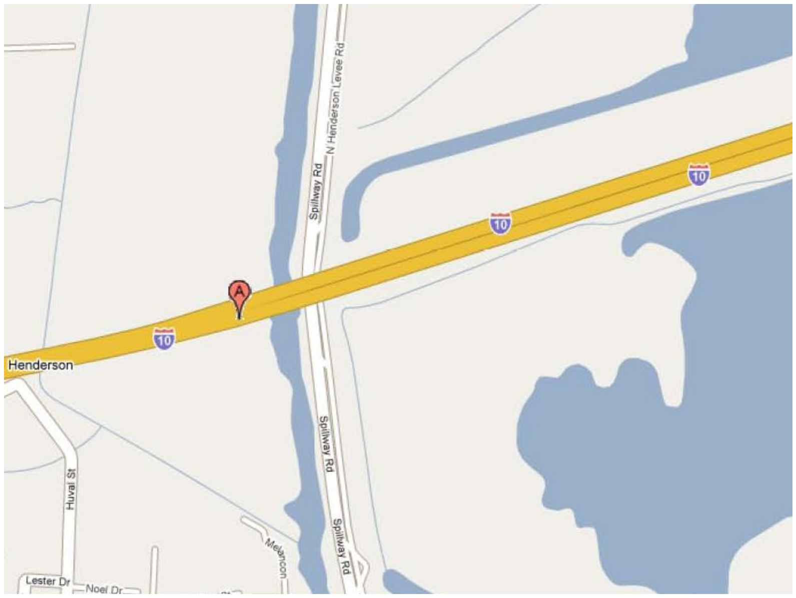


Figure 12
Location of RVD #22 near milepost 117 on I-10 eastbound

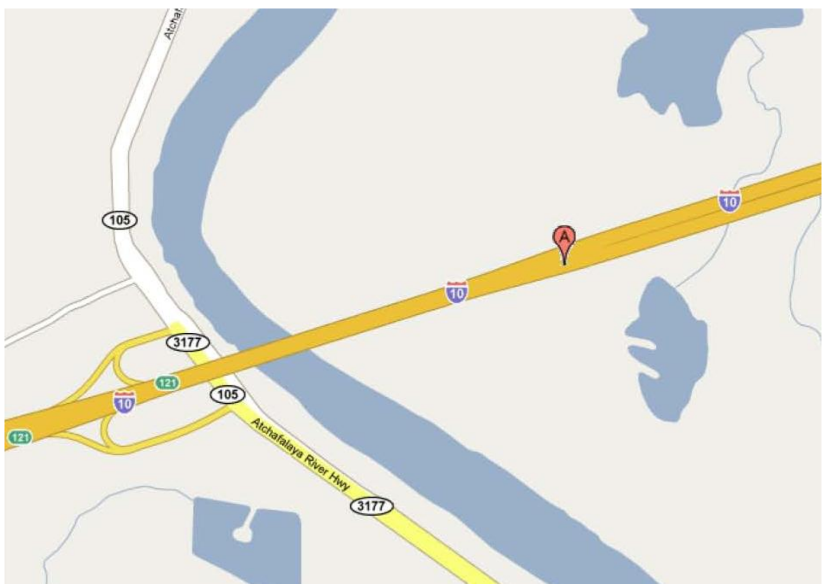


Figure 13
Location of RVD #23 near milepost 122.1 on I-10 eastbound

Data Collection System

In order to collect traffic data from each of the four RTMS units, it was necessary to establish a method of communication with the field devices. The data communication options shown in Figure 14 were considered as viable solutions to collect the data remotely in real time. This would eliminate the need for making frequent site visits and for the use of storage devices. The most efficient method of communication that was pursued by the research team involved in streaming the data wirelessly over a cellular network. To build this system and integrate it with the exiting RTMS units, the following equipment was needed:

1. Cluster controller: This device is primarily used to poll and store the data obtained from the RTMS devices until it is pushed to a remote client (see Figure 15). The maximum storage time possible on this device is one month.
2. Raven EDGE Version 2.01 cellular modem: This modem is required to transfer the data collected by the RTMS devices and polled by the cluster controller via the Internet (see Figure 15). Cellular service is required to connect to the modem in real time over a Transmission Control Protocol/Internet Protocol (TCP/IP) network.
3. Radio: This is required for communication between the RTMS devices and the cluster controller located at the tower (see Figure 15).
4. Antenna: This is mounted on the outside of the tower, where all the equipment is located (Figure 16). A Radio Frequency (RF) cable is run through the opening to the inside of the tower and connects to the cellular modem.
5. Personal computer: At the remote end, a personal computer with access to the Internet is required to connect to the modem.
6. Software: On the remote personal computer, where the data are compiled in real time, Wide Area Traffic Event Reporting (WATER) software is required. WATER requires a Structured Query Language (SQL) server to be installed and set up on the remote computer. The WATER/SQL system is designed to collect real time traffic data from multiple RTMS sensors. It runs as high priority process and places real time data collected from RTMS sensors into the SQL database.

Figure 17 shows the full data flow diagram and the communication links between all the components. Every 30 seconds, a traffic data packet containing vehicle counts by vehicle class, speed, and lane occupancy is transmitted from each of the four RTMS devices in the field to the tower via radio signal. The data packets are then transmitted from the radio device to the cluster controller where it is stored. The link between the cellular modem and the cluster controller allows the data to flow through wireless communication to a remote PC (located at the transportation research lab of Louisiana State University). The WATER/SQL system running on the remote PC retrieves the data continuously over TCP/IP link and compiles it in the database server. Each data packet has a time and date stamp as well as the RTMS unit it was transmitted from. Description of the database tables and their contents is provided in the next section.

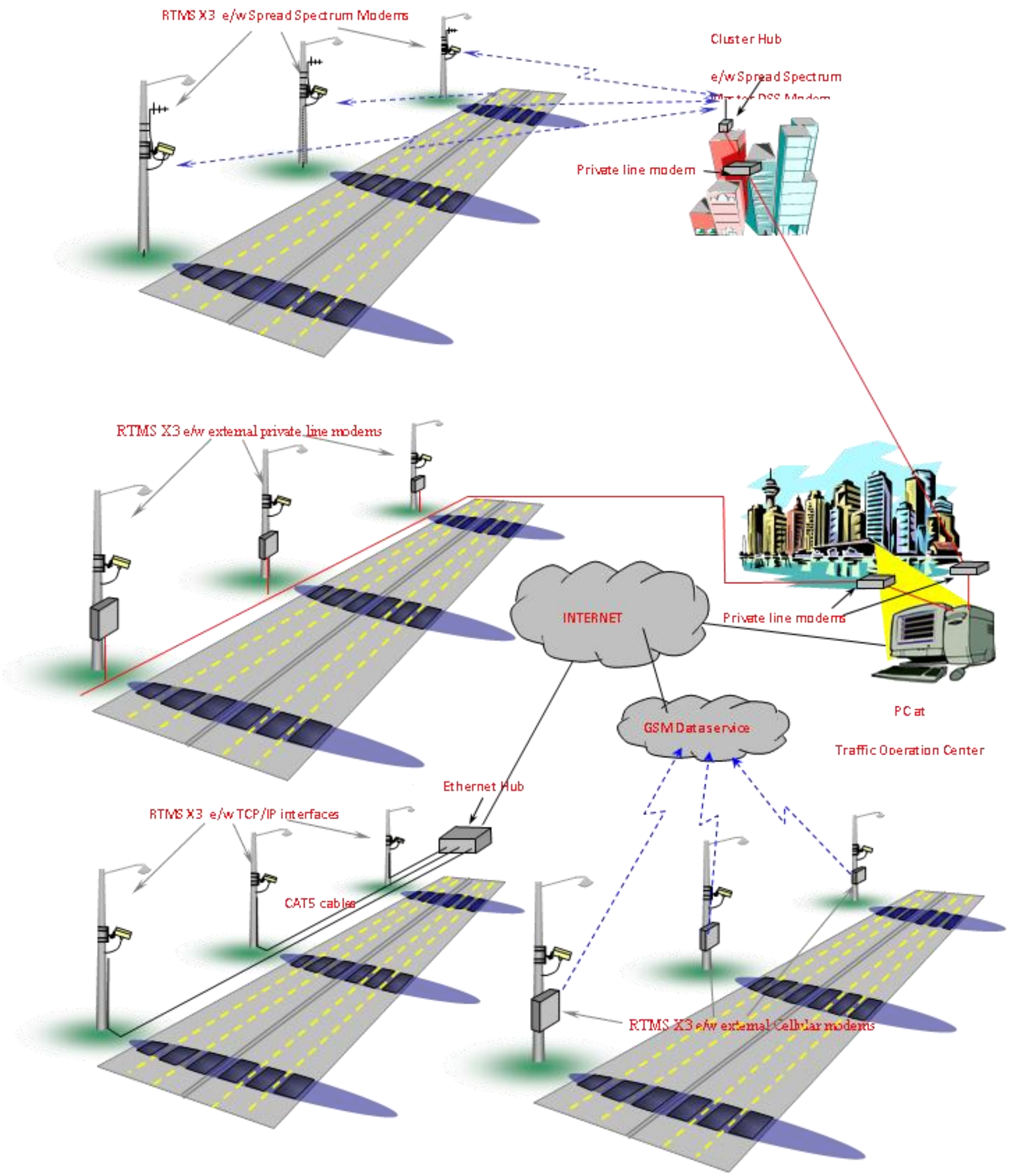


Figure 14
Data communication options

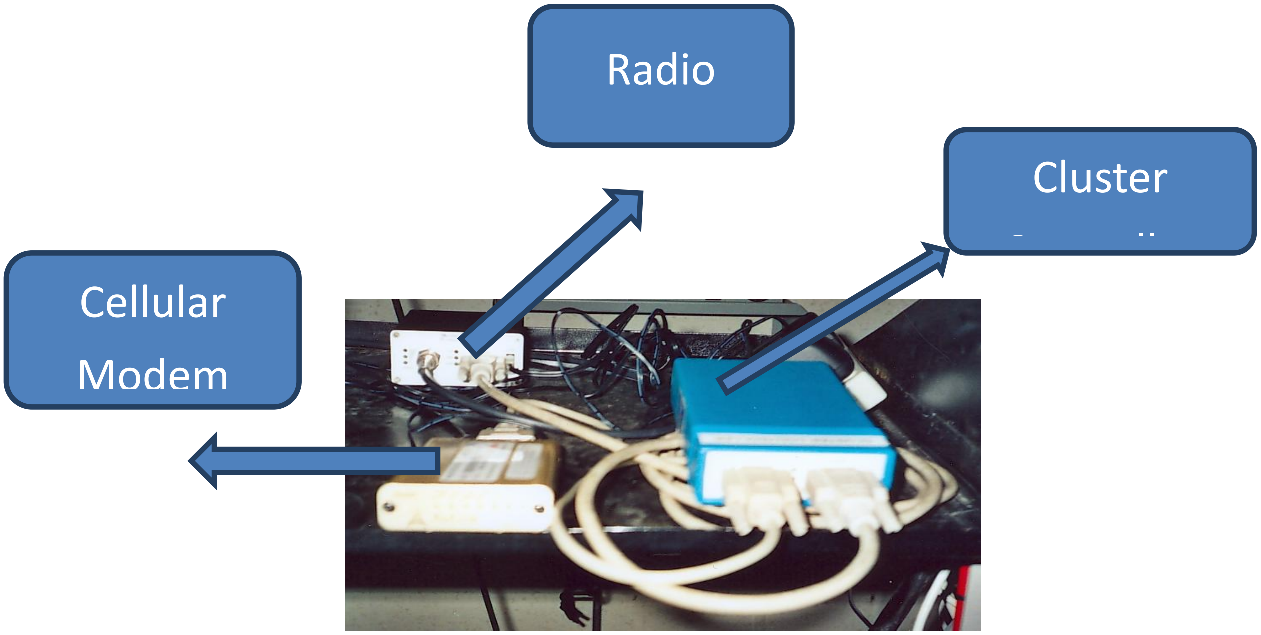


Figure 15
Cluster controller, radio, and cellular modem at Butte La Rose tower

Figure 16
RTMS antenna at Butte La Rose tower

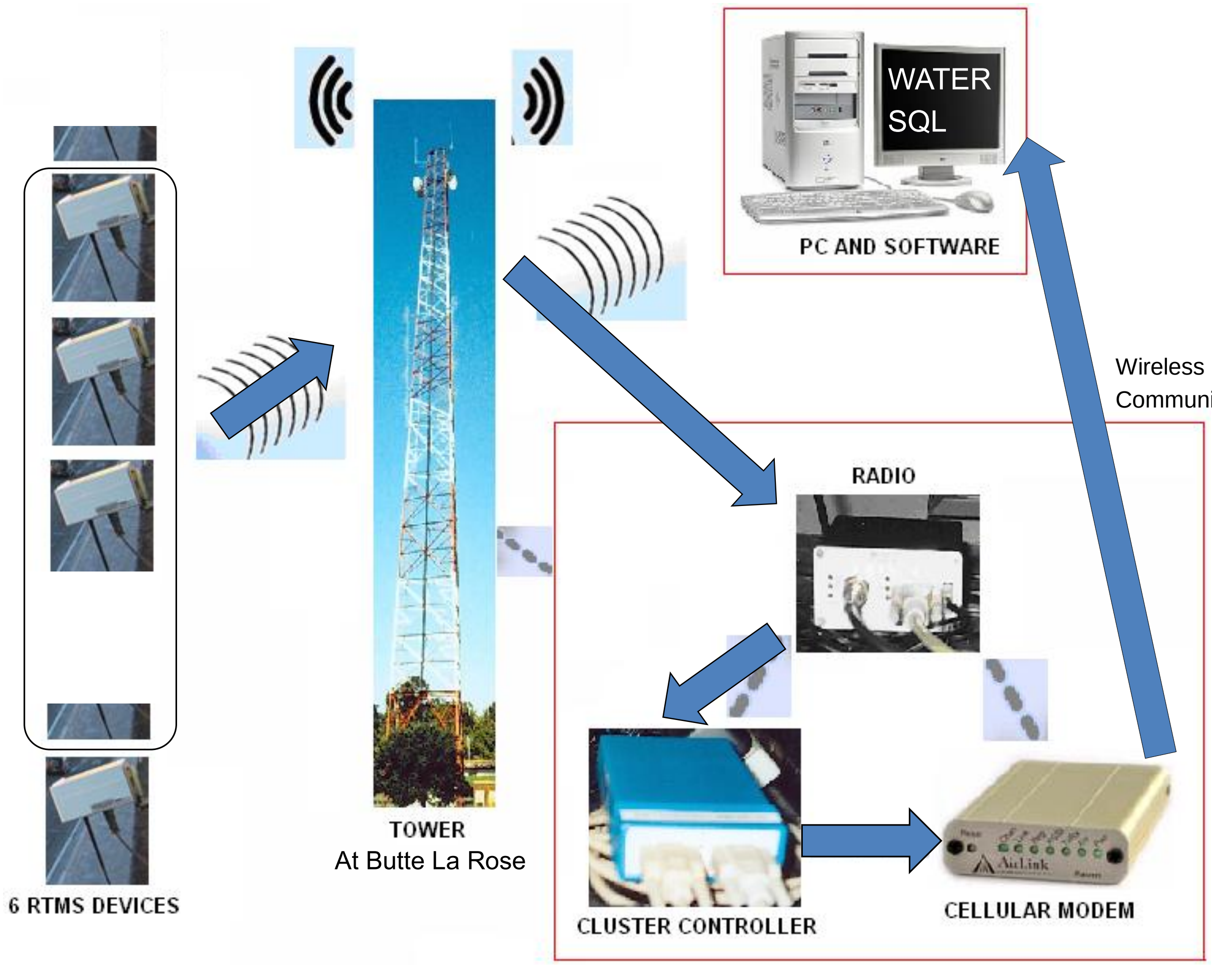


Figure 17
Traffic data flow diagram for the Atchafalaya Bridge

WATER/SQL System and Database Schema

The WATER/SQL system creates and stores the traffic data in separate database tables. Table 4 shows a snapshot of the database table "tblRtmsDataMain" where real time data are compiled from the RTMS devices. The table contains volume, speed, and lane occupancy from each RTMS device, polled every 30 seconds. The volume data are classified by vehicle type into one of four categories: passenger cars, mid-size vehicles, long trucks, and extra-long trucks. For each record in the database table, the time stamp is also included for each observation. Similarly, Table 5 shows the schema for the archived data for all previously received RTMS data. The configuration information for the RTMS devices and WATER/SQL utility is also stored in a database table "tblRtmsSetup," as shown in Table 6. Appendix A shows the WATER/SQL setup instructions.

Table 4
Schema of the database table "tblRtmsDataMain"

Column Name	Type	Description
RTMS_NETWORK_ID	int	RTMS Network ID of the reporting RTMS unit. Not the same as the RTMS ID.
RTMS_NAME	char	The name associated with the RTMS as defined by WATER/SQL Station Manager – Network Configuration
Zone	int	RTMS Zone number for which the statistics are reported
ZoneLabel	char	Label of the zone as defined by the WATER/SQL Station Manager
Station_Name	char	Station name as defined by the WATER/SQL Station Manager
Speed	int	Side Fired: Average speed for the last reported message period. Forward Looking: Speed bin based on zone number. Zone 1..7: Speed Bin 1..7 Zone 8: Undetermined Speed Bin
FWDLK_Speed	int	Forward looking average speed for the last reported message period. (F0 if the unit is in Side-Fired mode)
Volume	int	Volume count for the last reported message period
Vol_Mid	int	Midsize Vehicle Volume count for the last reported message period
Vol_Long	int	Long Vehicle Volume count for the last reported message period
Vol_Extra_Long	int	Extra Long Vehicle Volume count for the last reported message period
Occupancy	float	Zone occupancy for the last reported message period
MsgNumber	int	The RTMS Message Number of the last reported message period
DateTimeStamp	datetime	The SQL Server date and time of the data insertion. If the RTMS sends a date stamp, this value is used instead
SensorErrRate	float	Values other than 0.0 indicate transmission errors.
HealthByte	int	Reserved
SpeedUnits	bit	0/false if km/hr, 1/true if mph
Vol_Mid2	int	Midsize 2 Vehicle Volume count for the last reported message period
Vol_Long2	int	Long Vehicle 2 Volume count for the last reported message period

Table 5

Schema of the database table "tblRtmsHistory"

Column Name	Type	Description
DateTimeStamp	datetime	See tblRtmsDataMain
RTMS_NETWORK_ID	int	
RTMS_NAME	char	
Zone	int	
Speed	int	
FWDLK_Speed	int	
Volume	int	
Vol_Mid	int	
Vol_Long	int	
Vol_Extra_Long	int	
Occupancy	float	
MsgNumber	int	
SensorErrRate	float	
HealthByte	int	
SpeedUnits	bit	
Vol_Mid2	int	
Vol_Long2	int	

Table 6

Schema of the database table "tblRtmsSetup"

Column Name	Type	Description
RTMS_NETWORK_ID	int	Reserved For EIS Use Only
RTMS_NAME	char	
HW_ID	int	
Connection_Type	int	
IP_Addr	char	
Port_Num	int	
Cluster_Name	char	
WaitForDataTO	int	
Time_Corr	int	
Binary_1	binary	
Binary_2	binary	
Binary_3	binary	
Binary_4	binary	
Binary_5	binary	
Binary_6	binary	
Binary_7	binary	
Setup_Changed	bit	

DISCUSSION OF RESULTS

Traffic Behavior and Compliance

Trucks behave differently from passenger cars and play a significant role in highway safety and operation. To minimize the interaction between trucks and other regular size vehicles and to compensate for the inherent differences in operational characteristics, lane restriction and a differential speed limit (DSL) have been recently imposed at some locations along freeways where deemed necessary. LADOTD implemented both policies along the elevated section of I-10 over the Atchafalaya Basin in response to a serious crash that involved several vehicles and multiple fatalities in September 2003. This section focuses on the traffic characteristics and compliance behavior of traffic over the study section. More specifically, the effect of trucks on traffic flow is investigated and the effectiveness of right lane restriction and differential speed limit is evaluated.

As previously mentioned, the traffic flow and vehicle characteristics data were gathered at four different zones (sites) on the Atchafalaya segment of I-10 using a true presence detector, RTMS. The traffic data were primarily used to examine the behavior of cars and trucks, individually and collectively, along the study section. The analysis was conducted by applying a variety of statistical methods or techniques to reveal the main characteristics. This includes basic statistics, regression analysis, and pair-wise comparisons, as described in detail in this chapter.

Traffic Data Screening and Preparation

The study section of I-10 was monitored continuously over the time period of June 11, 2007, through September 22, 2007. Preliminary screening of the collected data was conducted to remove all records with zero vehicle counts and to convert the speed units from kph to mph. Based on the RTMS vehicle classification system, trucks were assumed to belong to the predefined class categories “long” and “extra long.” For statistical analysis, the data were also aggregated over 5-min. intervals to suppress high random fluctuations in the 30-sec. observations. For vehicle counts, the number of vehicles in each vehicle class was added up over 5-min. intervals. Speed and lane occupancy were aggregated using the average values weighted by the total vehicle count as follows:

$$\overline{S} = \frac{\sum (v_i * s_i)}{\sum v_i} \qquad \forall i \in 1{:}10 \qquad (1)$$

$$\overline{O} = \frac{\sum (v_i * o_i)}{\sum v_i} \qquad \forall i \in 1{:}10 \qquad (2)$$

where,
$\overline{S}$ = average 5-min. speed;
$\overline{O}$ = average 5-min. lane occupancy;
v_i = total vehicle count for 30-sec. interval, i;
s_i = average speed for 30-sec. interval, i; and
o_i = lane occupancy for 30-sec. interval, i.

Basic Traffic Characteristics

This section presents the basic statistical analysis results and the traffic characteristics in terms of distributions. For graphical illustration, the Statistical Analysis Software (SAS) CAPABILITY procedure was used to generate the histograms for speed, volume, lane occupancy, and traffic composition (truck percentage). For each individual traffic variable, both overall distribution and individual lane distribution at each site are presented and compared. Moreover, basic statistics for each traffic parameter is presented in terms of mean, standard deviation, range, and quantiles. Scatter plots were also generated to illustrate the relationships between different traffic variables. This section consists of two parts. The first part shows the distributions for various traffic parameters, while the second part focuses on the relationships between different parameters as exhibited by the scatter plots.

Distributions of Traffic Parameters

This section presents the main characteristics of the traffic parameters in terms of their probability distributions and descriptive statistics. This includes speed, volume, lane occupancy, and truck percentages.

Traffic Parameter (Speed). Figure 18 shows the distribution of the overall traffic speed data for all sites. The distribution shape appears to closely match a normal distribution with a mean of 62.6 mph and standard deviation of 6.3 mph. The low coefficient of variation (10 percent) implies a high central tendency of the traffic speed. Most of the observations fell in the range of 49 to 76 mph.

The speed distribution was also examined by lane at each of the four sites. Figure 19 and Figure 20 show the distributions of traffic speed on the right and left lanes at site 20. Similarly, the distribution of traffic speed at each lane appears to be normal and bell-shaped. For the right lane at site 20, the mean and standard deviation were 55.73 and 3.64 mph, respectively. For the left lane, the mean and standard deviation were 65.72 and 4.53 mph, respectively. This clearly indicates that the overall speed on the left lane was much higher than that on the right lane. Also, speed variation on the left lane was slightly higher than that on the right lane. Such observation is mostly attributed to the differential speed limit applied at the study section. Similar patterns were observed for the traffic speed distributions at the other three sites as shown in Figure 21 though Figure 26.

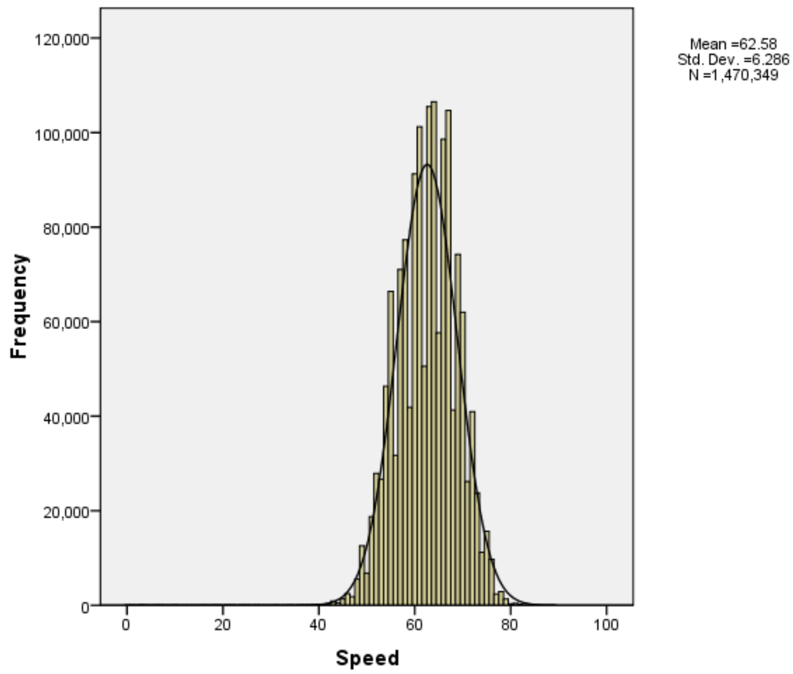


Figure 18
Speed distribution for all lanes and sites

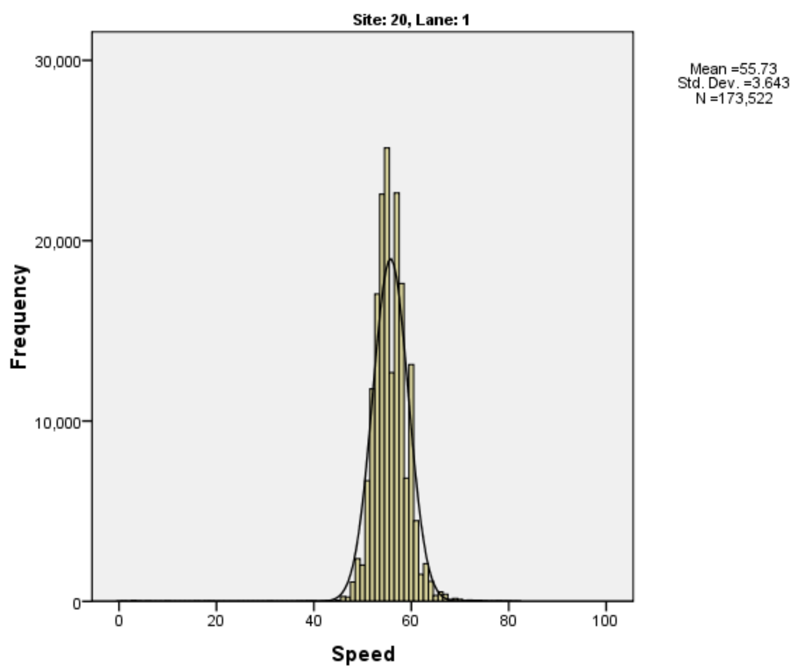


Figure 19
Speed distribution for the right lane (lane 1) at site 20

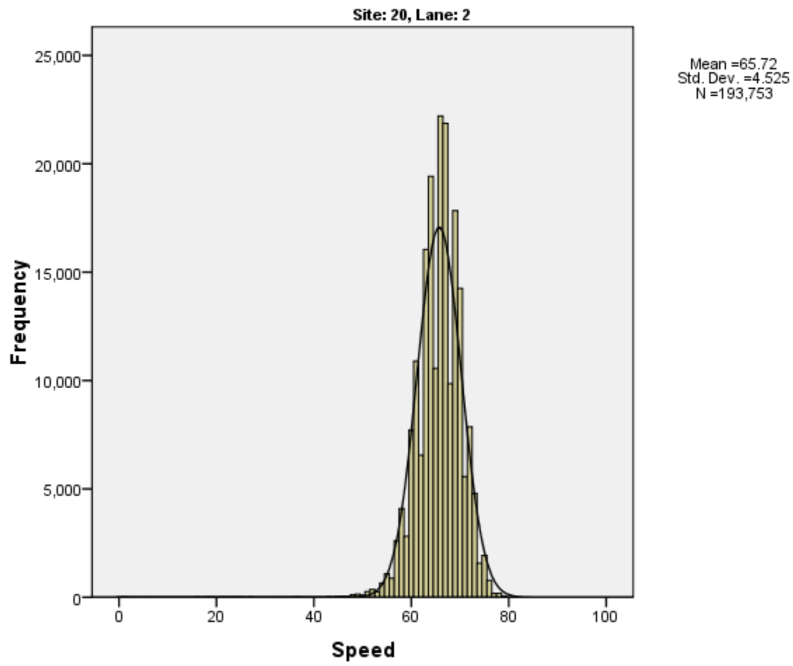


Figure 20
Speed distribution for the left lane (lane 2) at site 20

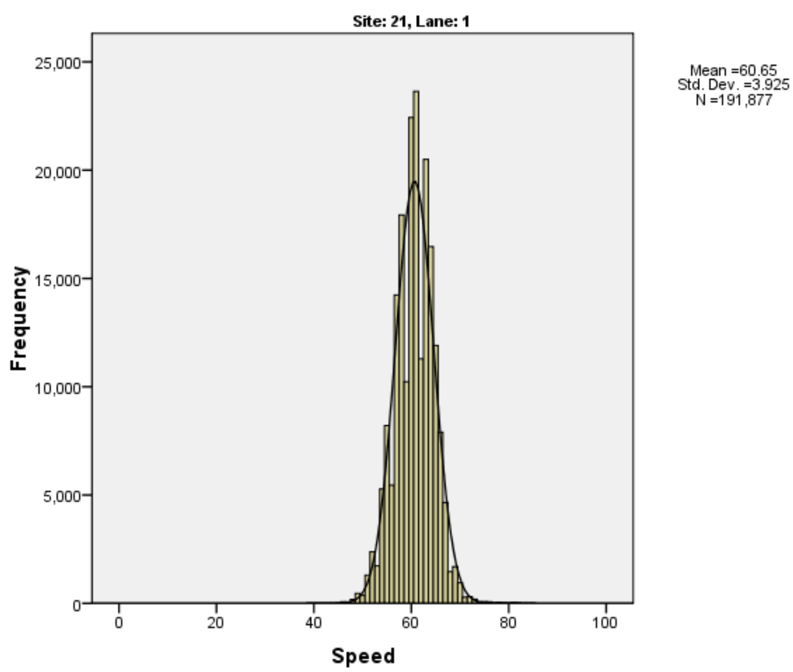


Figure 21
Speed distribution for the right lane (lane 1) at site 21

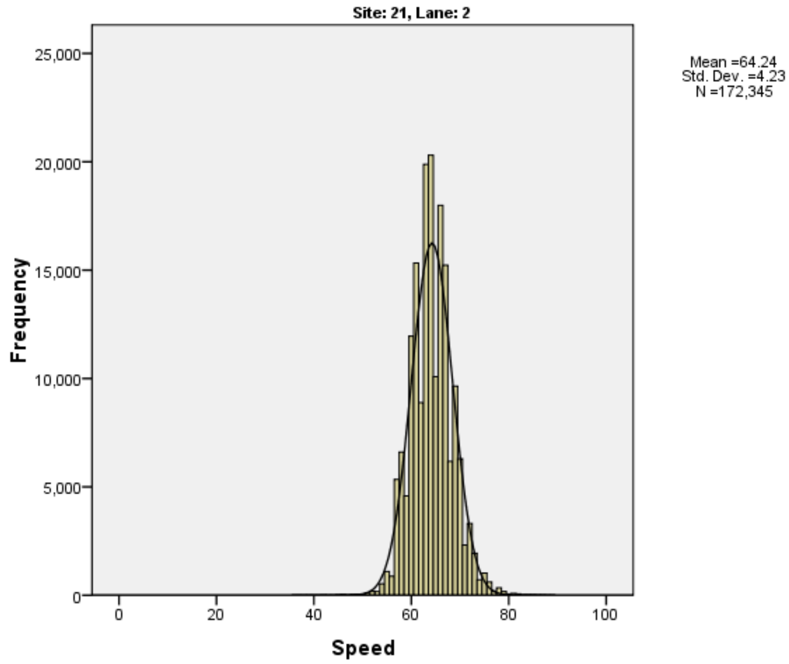


Figure 22
Speed distribution for the left lane (lane 2) at site 21

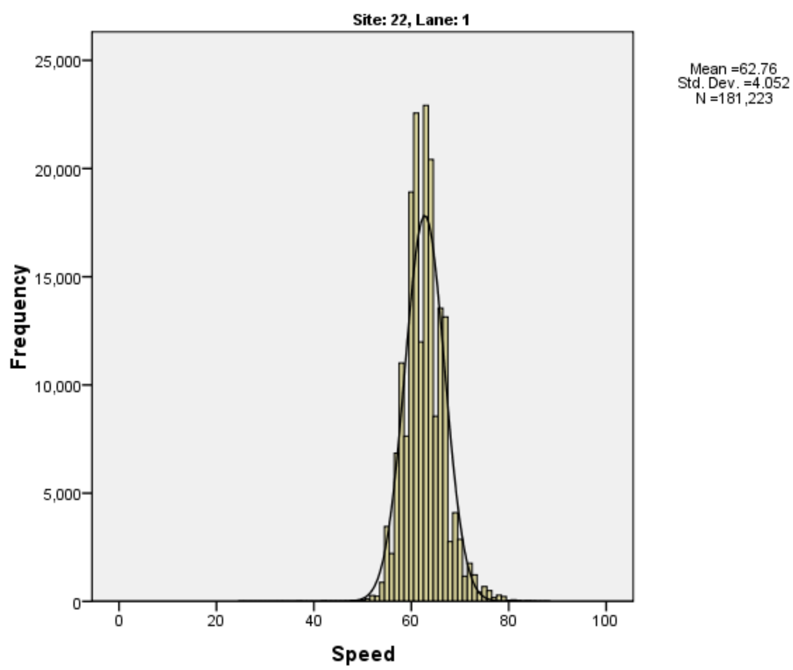


Figure 23
Speed distribution for the right lane (lane 1) at site 22

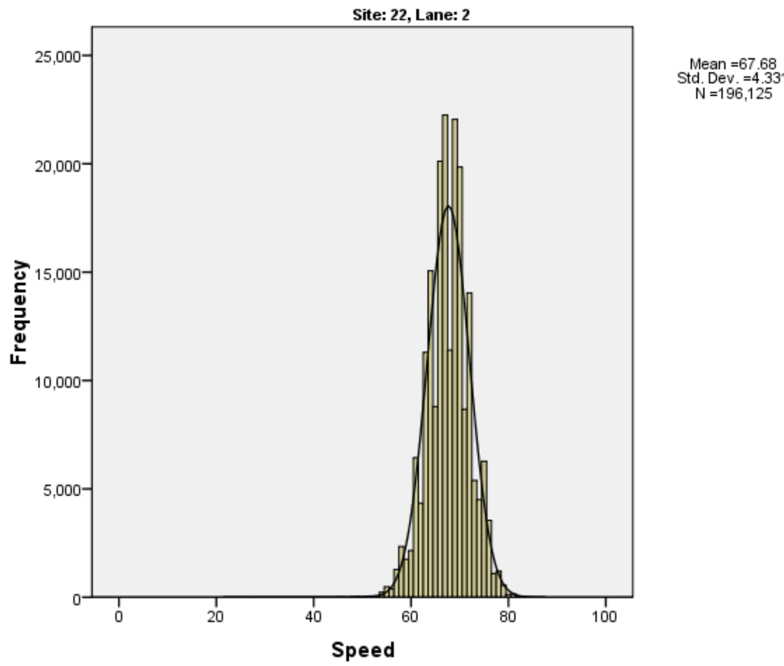


Figure 24
Speed distribution for the left lane (lane 2) at site 22

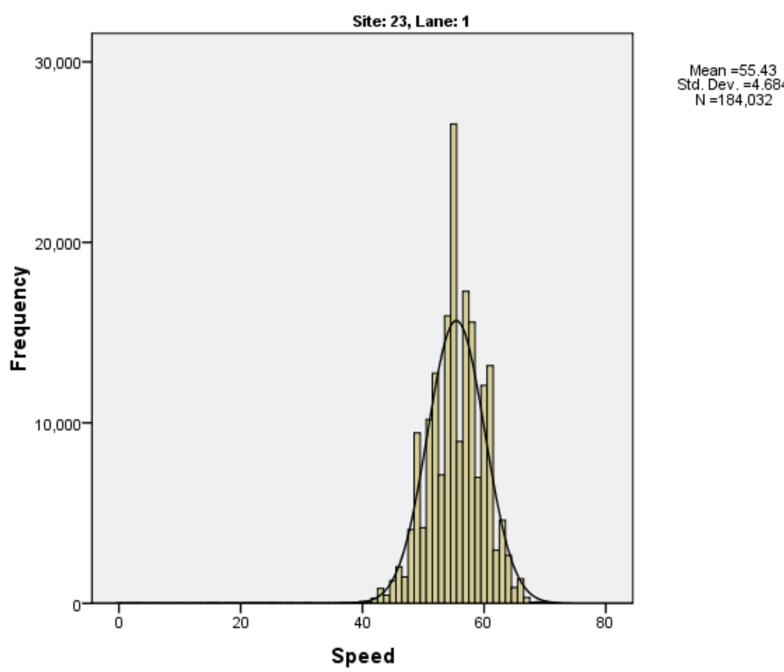


Figure 25
Speed distribution for the right lane (lane 1) at site 23

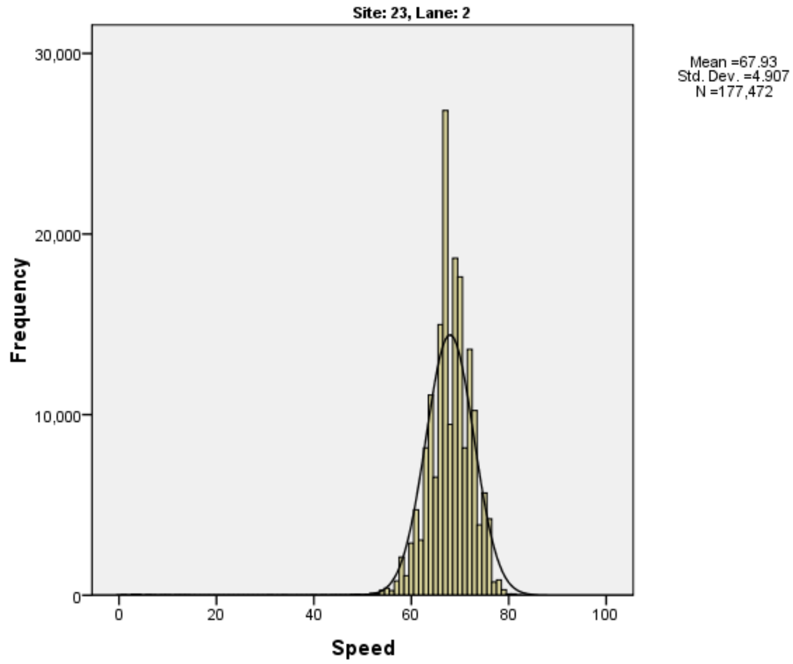


Figure 26
Speed distribution for the left lane (lane 2) at site 23

Table 7 shows a summary of the basic characteristics of the speed distributions for each lane at each site. The table shows the mean, standard deviation, and quantiles for each distribution. It can be seen from the table that the speed on the right lane is consistently lower than that on the left lane. For sites 20 and 23, the speed on the right lane was very close to the imposed speed limit of 55 mph for trucks. The right-lane speed for sites 21 and 22, however, was slightly higher than 55 mph. Site 22 is located near the eastbound entrance of the study section where the speed limits are reduced. This may explain the relatively high average speed spotted on the right lane of that site. Figure 27 and Figure 28 show the cumulative distribution plots of speed for each lane and site. The figures show that most speed observations ranged between 50 to 70 mph and that the right lanes exhibited generally lower speeds than the left lanes at all quantile levels.

To reveal the effect of time of day on the traffic speed characteristics, a series of plots were produced for each lane and site. Figure 29 shows the mean speed on the right and left lanes at each site by hour of day. The figure clearly shows that the mean speed on the right lane is consistently lower than that on the left lane for every hour of the day. The figure also shows that the mean speed on both lanes seems to increase slightly during nighttime. For sites 20 and 23, the mean speed on the left lane appears to exceed that on the right lane by an average of 10 mph. This difference drops to nearly 5 mph for sites 21 and 22, which are located near the end and beginning of the bridge in the eastbound and westbound directions, respectively. It should also be noted that the mean speed on the right lane of sites 21 and 22 was relatively higher (around 60 mph or more) than that on the right lane of sites 20 and 23 (around 55 mph).

Table 7
Basic statistics summary of traffic speed

		Right Lane				Left Lane				Overall
Site		20	21	22	23	20	21	22	23	
Mean		55.73	60.65	62.76	55.43	65.72	64.24	67.68	67.93	62.58
Standard Deviation		3.64	3.92	4.05	4.68	4.53	4.23	4.34	4.91	6.28
Quantile	100% Max	82	85	88	72	81	89	87	84	89
	99%	65	70	75	66	75	75	78	77	76
	95%	61	67	70	63	72	71	75	75	72
	90%	60	65	67	61	71	69	73	73	70
	75% Q3	58	63	65	58	69	67	70	71	67
	50% Median	55	61	63	55	66	64	68	68	63
	25% Q1	54	58	60	52	63	61	65	66	58
	10%	52	55	58	49	60	59	62	63	54
	5%	51	54	57	48	58	58	61	61	52
	1%	48	51	55	44	55	55	57	57	49
	0% Min	1	39	25	1	1	36	22	1	1

Figure 30 shows the percentage of speed observations exceeding 55 mph by lane and hour of day for each of the four sites. The figure shows that nearly 95 percent of the speed observations on the left lane for all sites exceeded 55 mph. This was expected since the speed limit for the left lane is set to 60 mph. At sites 21 and 22 nearly over 85 percent (site 21) and 96 percent (site 22) of the speed observations exceeded the 55 mph speed limit set for trucks on the right lane. Since the right lane is used by cars (speed limit of 60 mph) and trucks (speed limit of 55 mph), the aggregate average speed is expected to exceed 55 mph. This is consistent with the earlier observations at the both sites. The effect of truck compliance behavior on the overall speed of the right lane will be further examined later using more advanced statistical analysis. At the intermediate sites (20 and 23) nearly 40 percent of the speed observations exceeded the 55 mph speed limit during daytime. This ratio seemed to increase to 60 percent during nighttime, which may imply more compliance to speed limit and more presence of trucks on the right lane at intermediate locations during daytime.

This behavior is also exhibited by Figure 31, which shows the percentage of observations exceeding 60 mph by lane and hour of day. Most speed observations on the left lane exceeded 60 mph. Also, at sites 21 and 22, at least 45 percent and 65 percent, respectively, of the right-lane observations exceeded 60 mph during daytime. The ratios substantially increased to nearly 70 percent at nighttime. At the other sites, however, the percentages did not exceed 20 percent, even at nighttime.

This suggests relatively better compliance at intermediate sites and during daytime. The same trend was consistently observed at all sites for observations exceeding 65 mph as shown in Figure 32. Only 10 percent to 20 percent of the observations at sites 21 and 22 exceeded 65 mph, which is 10 mph above speed limit of the right lane. Virtually all observations at sites 20 and 23 did not exceed 65 mph for the right lane.

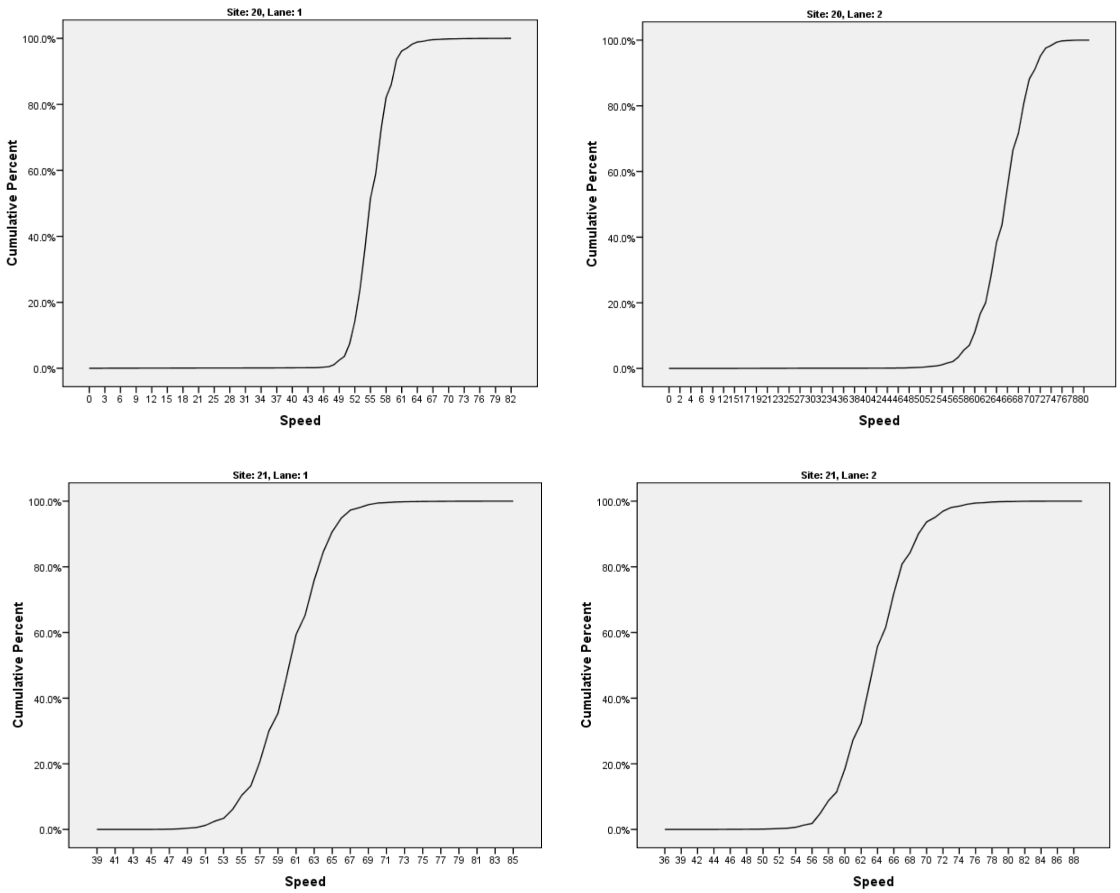


Figure 27

Cumulative distribution plots for traffic speed at sites 20 and 21

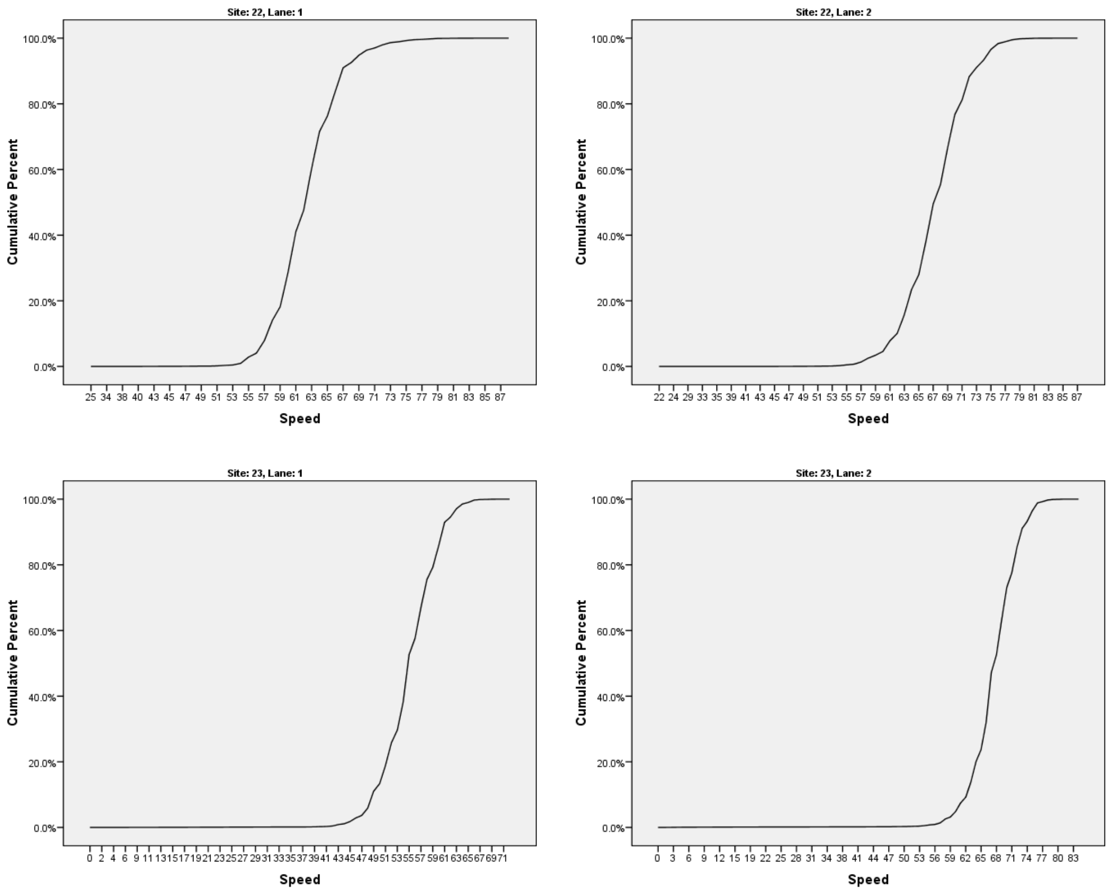


Figure 28
Cumulative distribution plots for traffic speed at sites 22 and 23

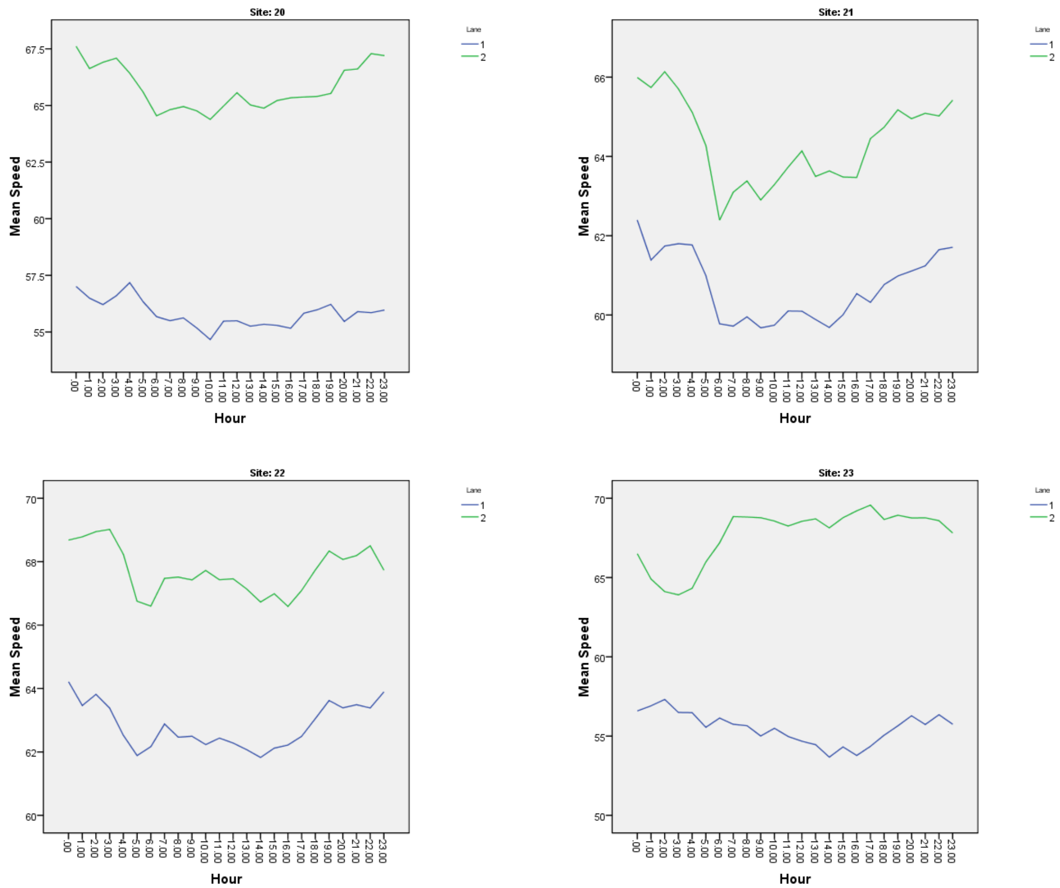


Figure 29
Mean speed by lane and hour of day for each site

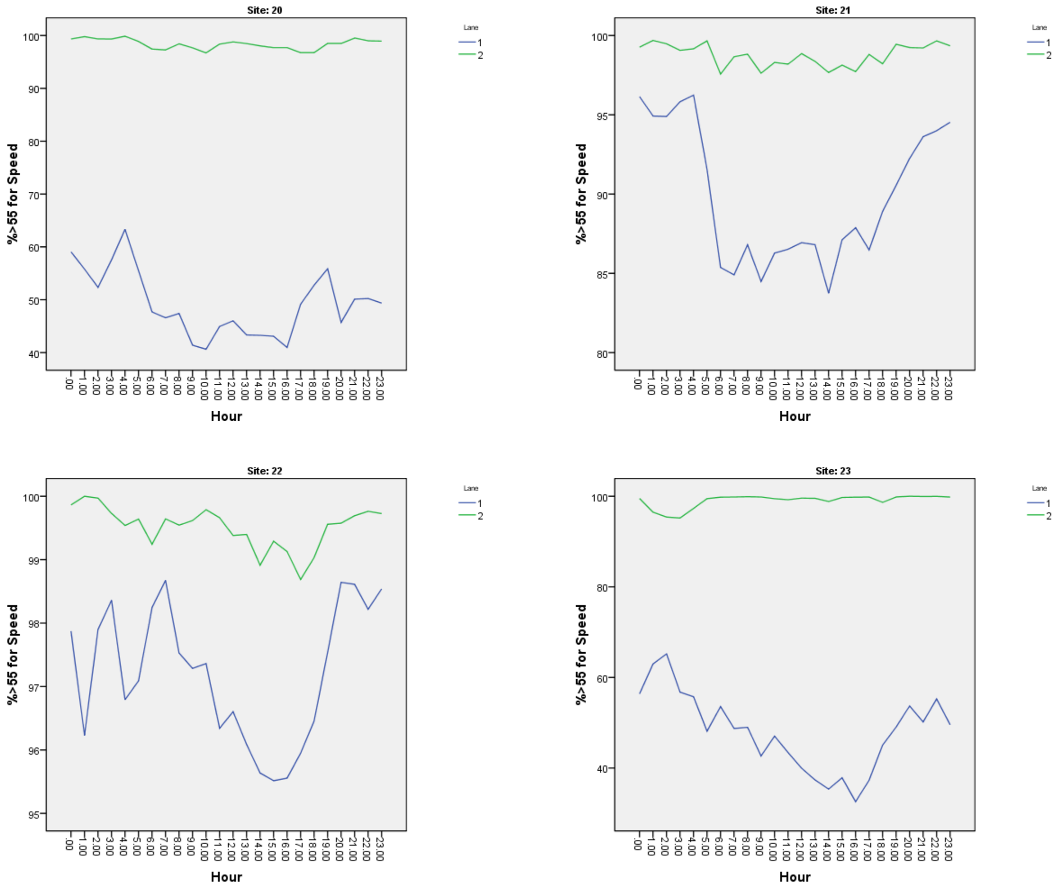


Figure 30

Speed observations exceeding 55 mph by lane and hour of day for each site

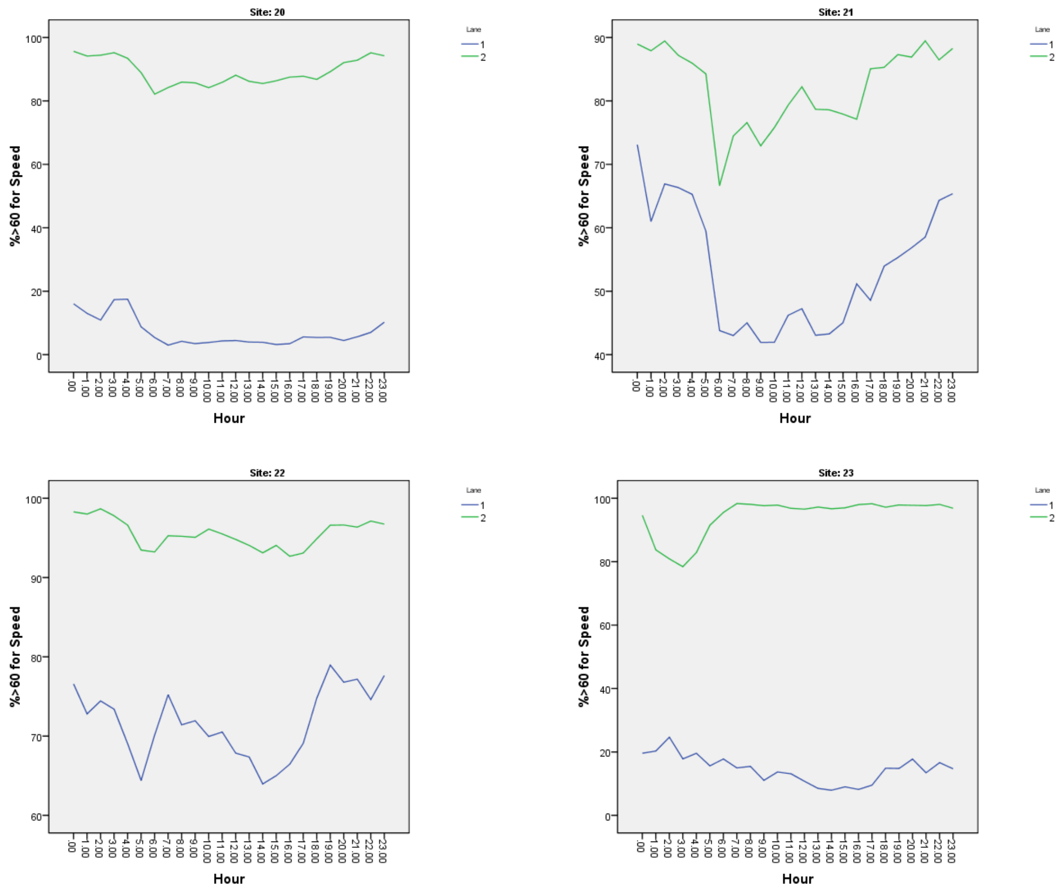


Figure 31

Speed observations exceeding 60 mph by lane and hour of day for each site

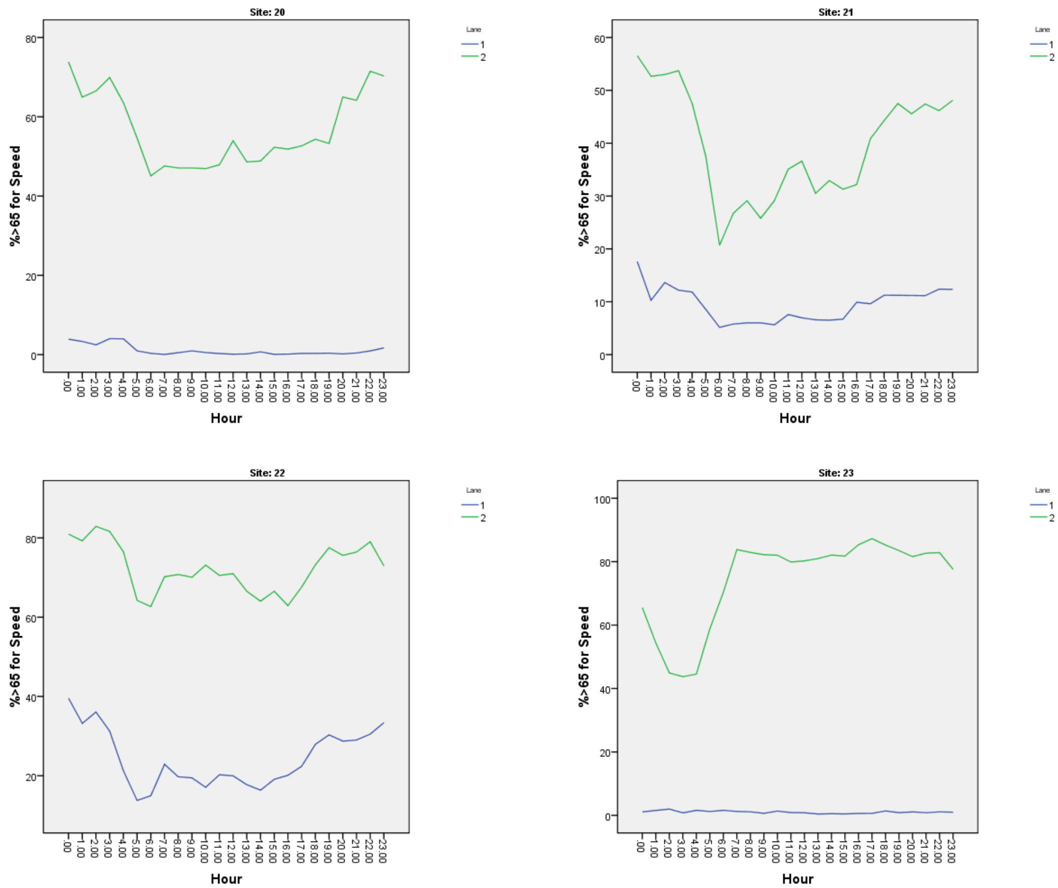


Figure 32

Speed observations exceeding 65 mph by lane and hour of day for each site

Traffic Parameter (Volume). The observed vehicle count data fell in the range of 1 to 20 vehicles measured in 30-sec. periods. The volume distribution for all lanes and sites is depicted in Figure 33. The overall mean and standard deviation were 3.9 and 3.1 vehicles per 30 sec., respectively. The coefficient of variation (CV) is 80 percent, which implies high variation. Figure 34 and Figure 35 show the distributions of volume on the right and left lanes at site 20. The mean and standard deviation of the volume for the right lane at site 20 were 4.02 and 2.55 vehicles/30 sec, respectively. For the left lane, the mean and standard deviation were slighter higher at values of 3.86 and 3.76, respectively. This implies that overall the left lane usage is slightly lower than the right lane with a relatively higher variation. Similar patterns were also observed for both lanes at the other three sites except site 23, as shown in Figure 36 through Figure 41.

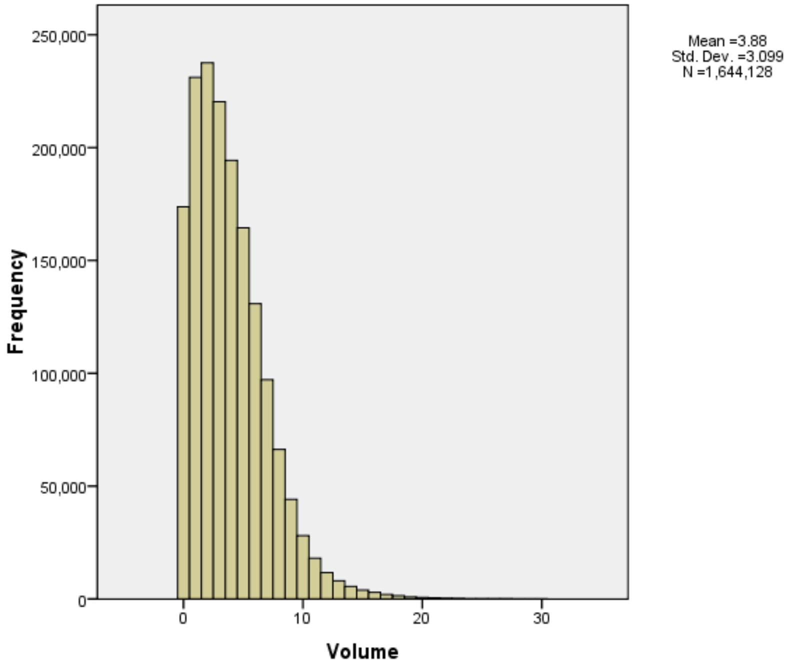


Figure 33
30-sec. volume distribution for all lanes and sites

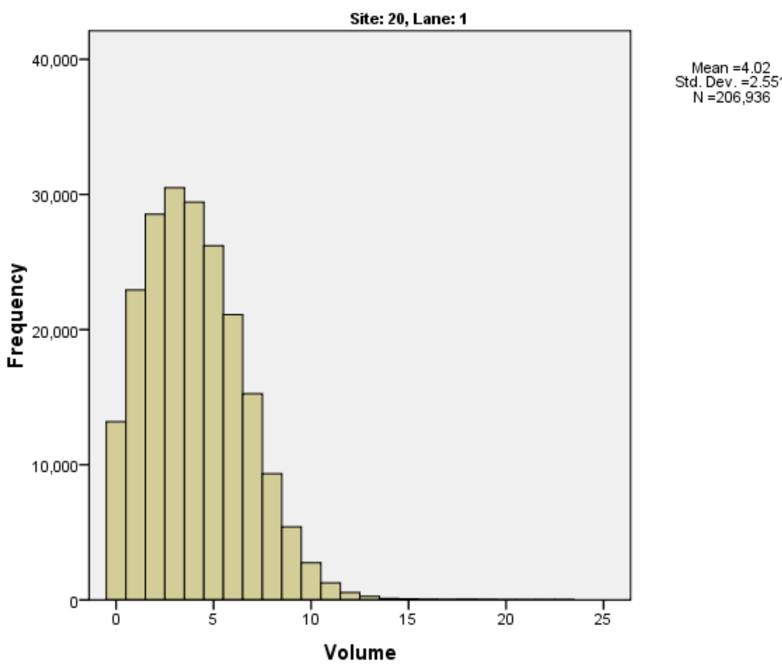


Figure 34
30-sec. volume distribution for the right lane at site 20

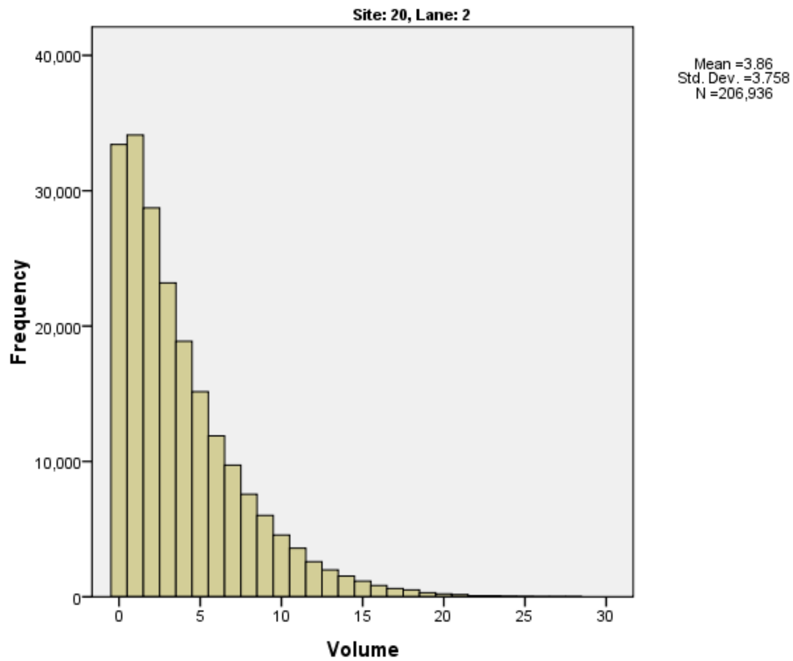


Figure 35
30-sec. volume distribution for the left lane at site 20

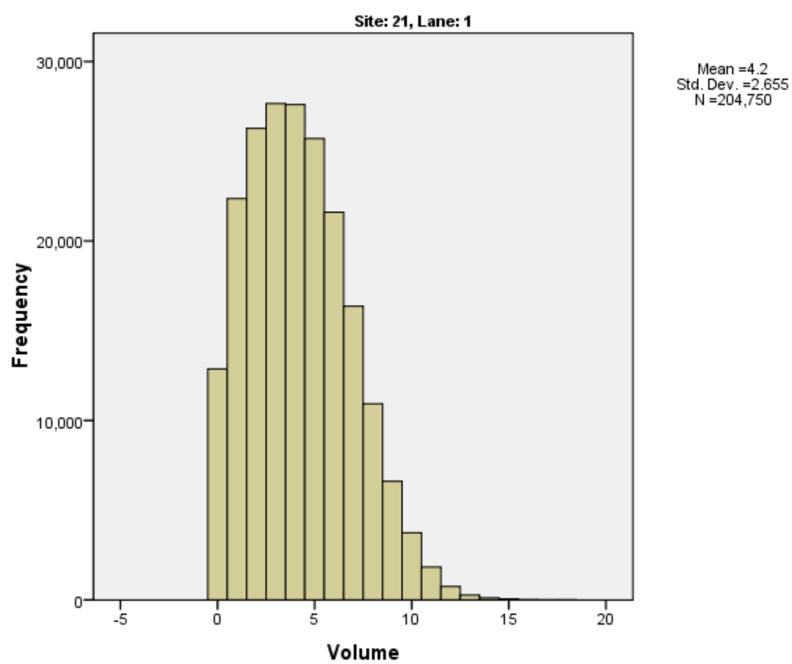


Figure 36
30-sec. volume distribution for the right lane at site 21

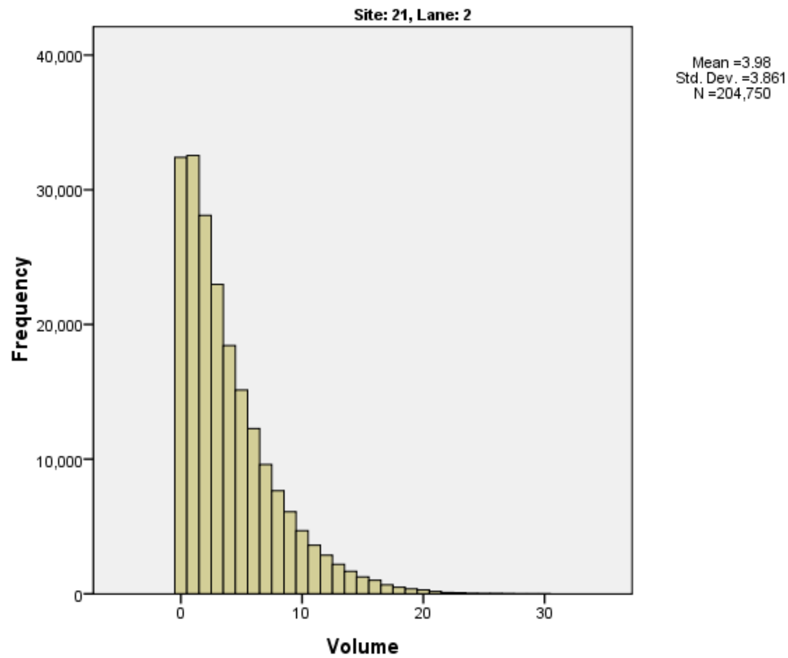


Figure 37
30-sec. volume distribution for the left lane at site 21

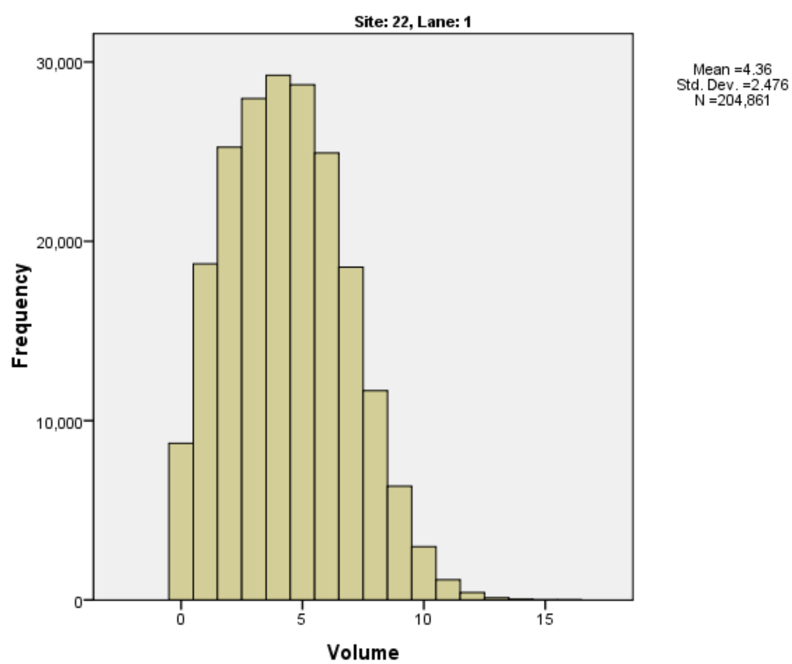


Figure 38
30-sec. volume distribution for the right lane at site 22

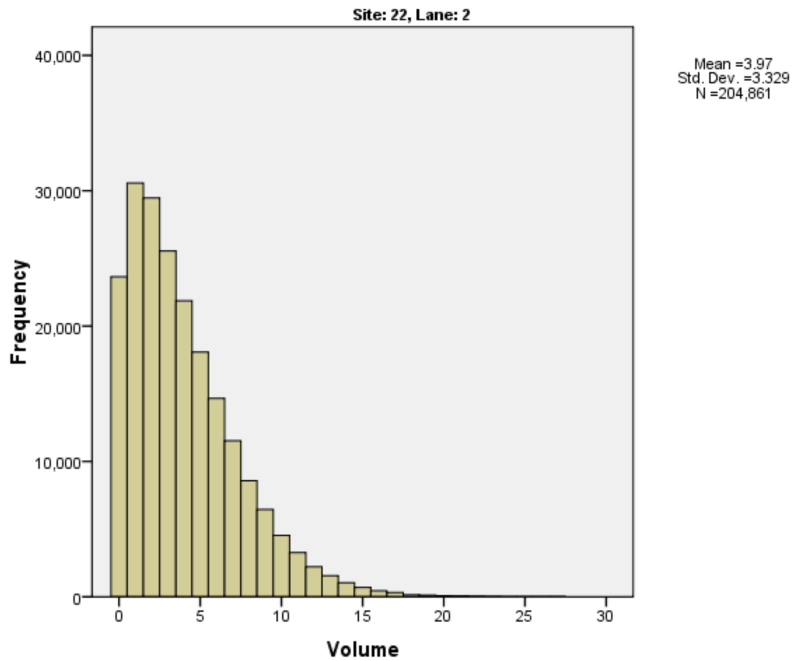


Figure 39
30-sec. volume distribution for the left lane at site 22

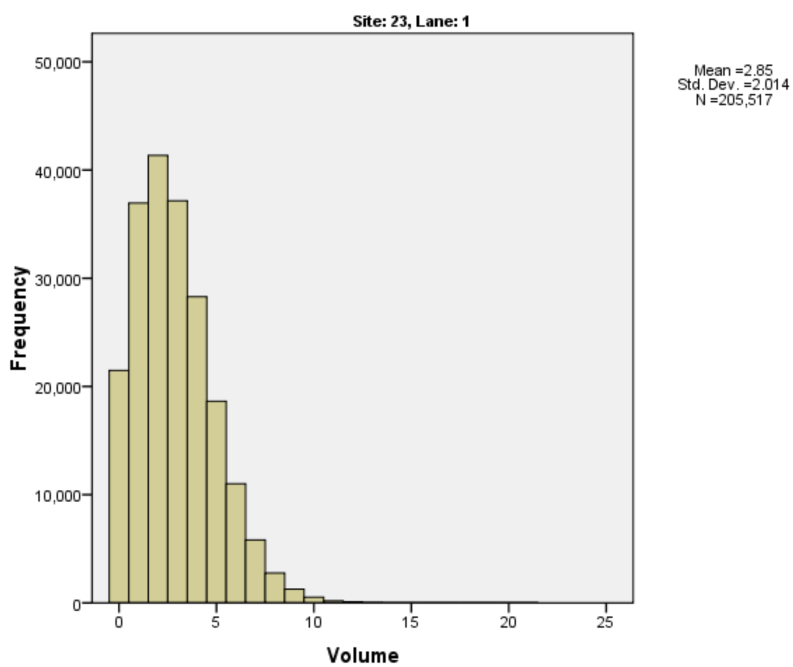


Figure 40
30-sec. volume distribution for the right lane at site 23

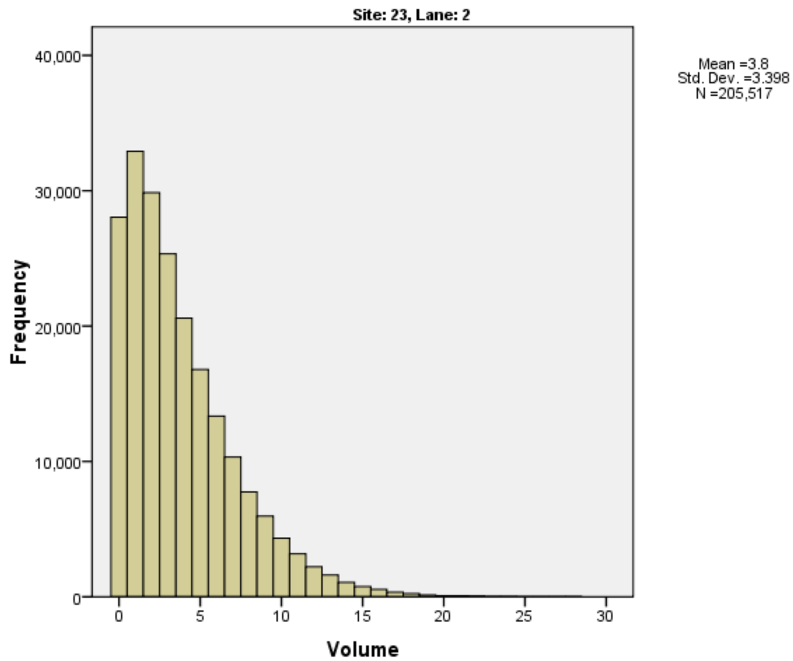


Figure 41
30-sec. volume distribution for the left lane at site 23

Table 8 shows a summary of the basic characteristics of the volume distributions for each lane at each site. The table shows the mean, standard deviation, and quantiles for each distribution. It can be seen from the table that the volume on the right lane is very comparable to that on the left lane. This implies that the distribution of traffic on both lanes is almost even or balanced in terms of vehicles. Figure 42 and Figure 43 show the cumulative distribution plots for the 30-sec. volume for each lane and site. The figures show that most volume observations ranged between 2 and 15 vehicles per 30 sec.

Traffic Parameter (Lane Occupancy). The lane occupancy distribution was also developed for all lanes and zones combined as shown in Figure 44. High lane occupancy indicates traffic congestion with relatively slow speeds, while low lane occupancy indicates free-flow conditions. Based on the overall distribution of lane occupancy, the observed occupancy did not exceed nearly 20 percent, which indicates free-flow to light traffic congestion. The basic statistics shows that nearly 95 percent of the observations were below 11 percent, which implies that free-flow conditions were dominant throughout the data collection period.

Table 8
Basic statistics summary of 30-sec. volume

		Right Lane				Left Lane				overall
Site		20	21	22	23	20	21	22	23	
Mean		4.02	4.2	4.36	2.85	3.86	3.98	3.97	3.80	3.88
Standard Deviation		2.55	2.66	2.48	2.01	3.76	3.86	3.33	3.40	3.10
Quantile	100% Max	22	18	16	21	28	30	27	28	30
	99%	11	11	10	9	17	17	15	15	14
	95%	9	9	9	7	12	12	11	11	10
	90%	8	8	8	6	10	10	9	9	8
	75% Q3	6	6	6	4	6	6	6	6	6
	50% Median	4	4	5	3	4	4	4	4	4
	25% Q1	3	2	3	2	2	2	2	2	2
	10%	2	1	2	1	1	1	1	1	1
	5%	1	1	1	1	1	1	1	1	1
	1%	1	1	1	1	1	1	1	1	1
	0% Min	1	1	1	1	1	1	1	1	1

Figure 45 and Figure 46 show the distributions of lane occupancy for both right and left lanes at site 20. Similar to the previous volume distributions, the lane occupancy distributions seem a little more skewed to the right with an average occupancy of nearly 3.9 percent and 3.5 percent for the right and left lane, respectively. The ranges and quantiles for each lane are close to those of the overall data. Similar trends were also observed for the occupancy data on both lanes at the other three sites as shown in Figure 47 through Figure 52. The basic statistics summary for all sites by lane is presented in Table 9. Cumulative distribution plots for all sites are also shown in Figure 53 and Figure 54.

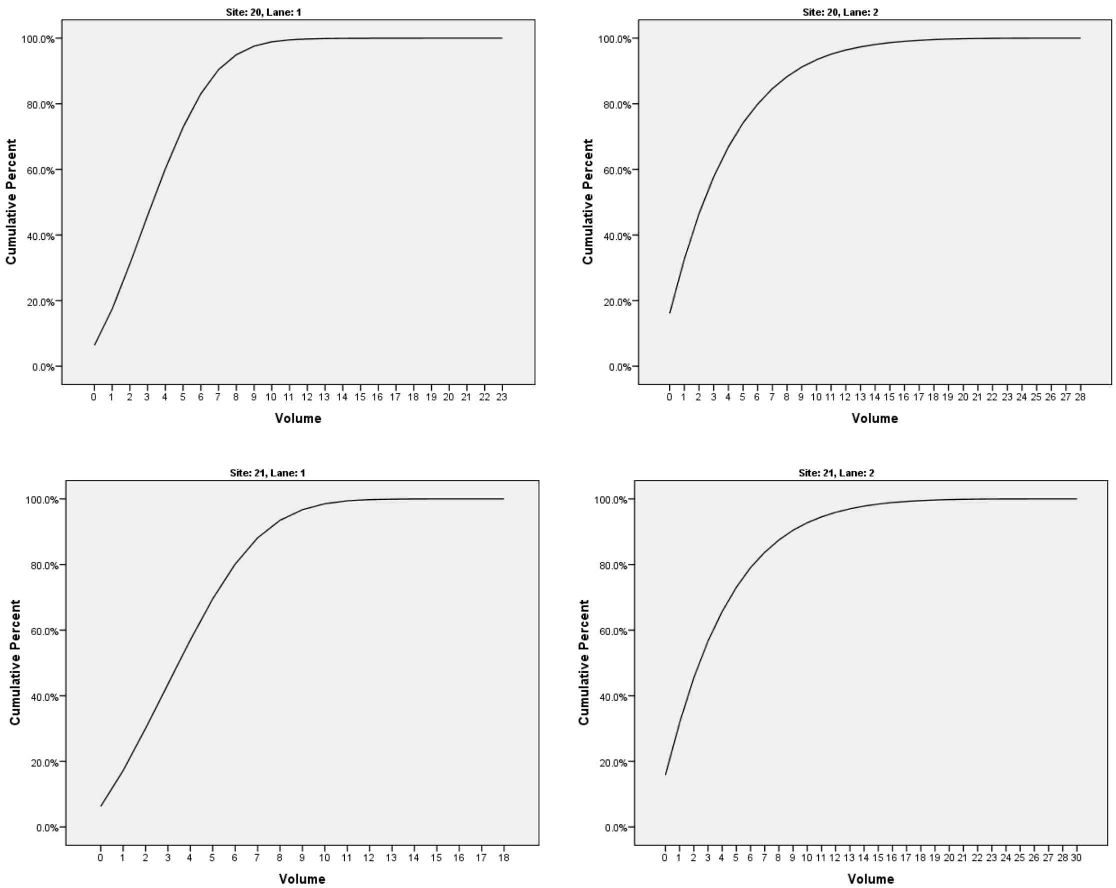


Figure 42
Cumulative distribution plots for 30-sec. volume for sites 20 and 21

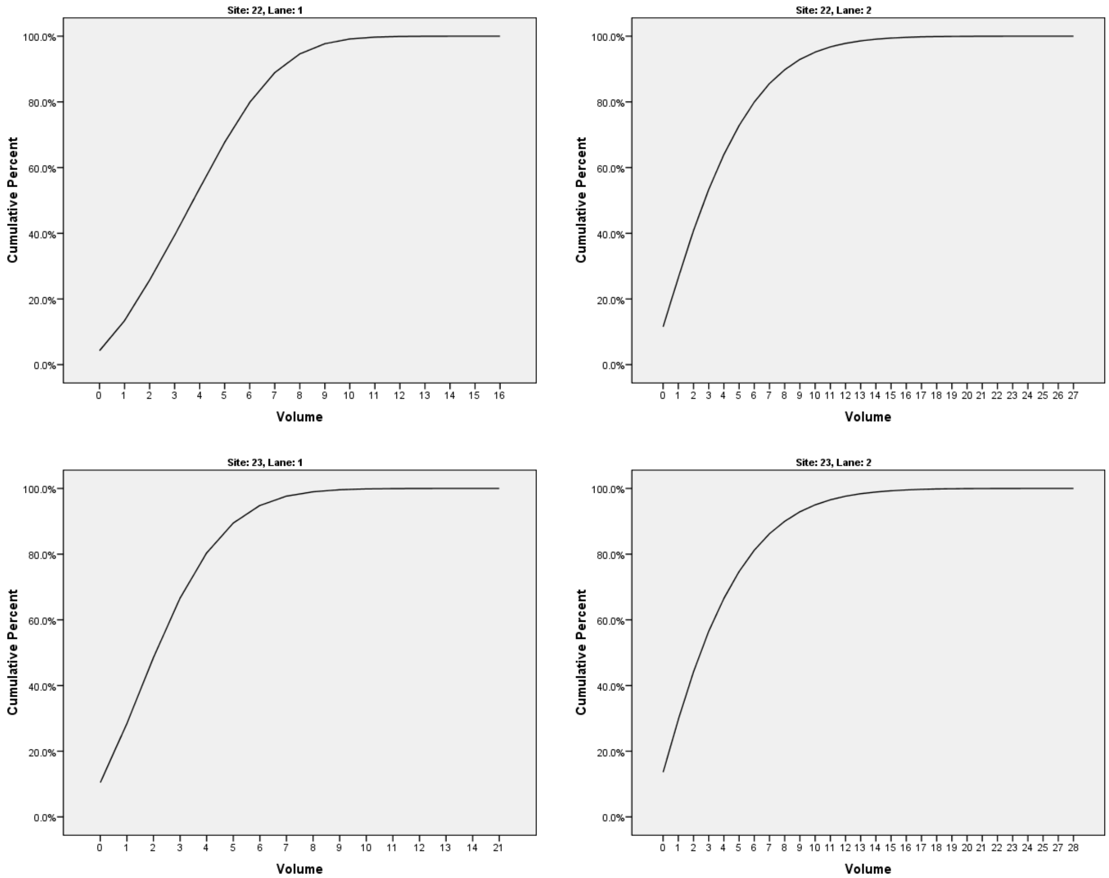


Figure 43
Cumulative distribution plots for 30-sec. volume for sites 22 and 23

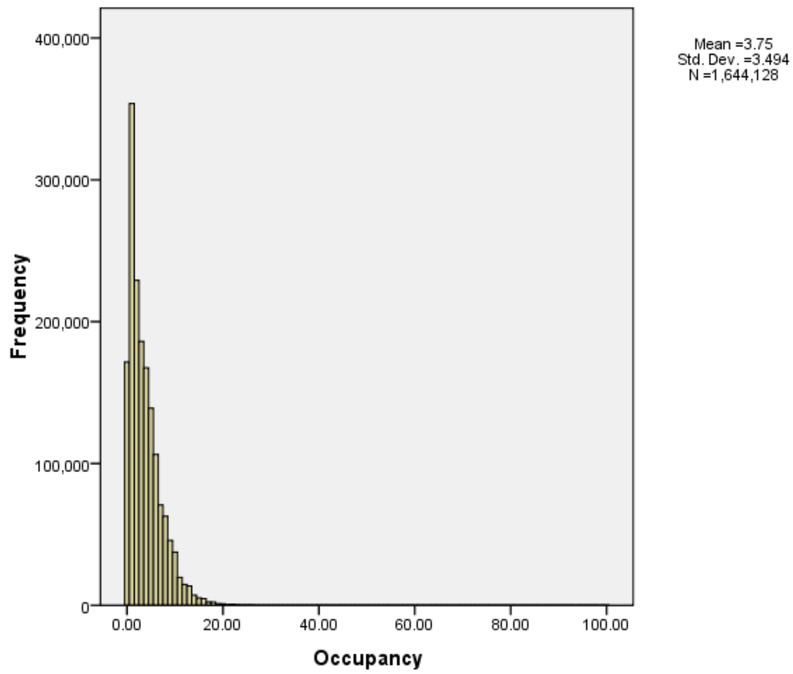


Figure 44
Lane occupancy distribution for all lanes and sites

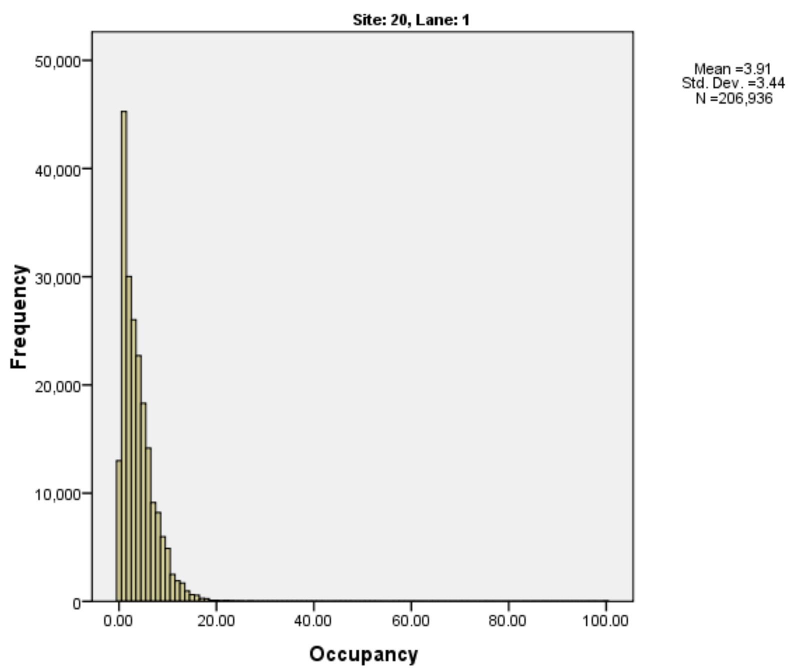


Figure 45
Histogram of occupancy for the right lane at site 20

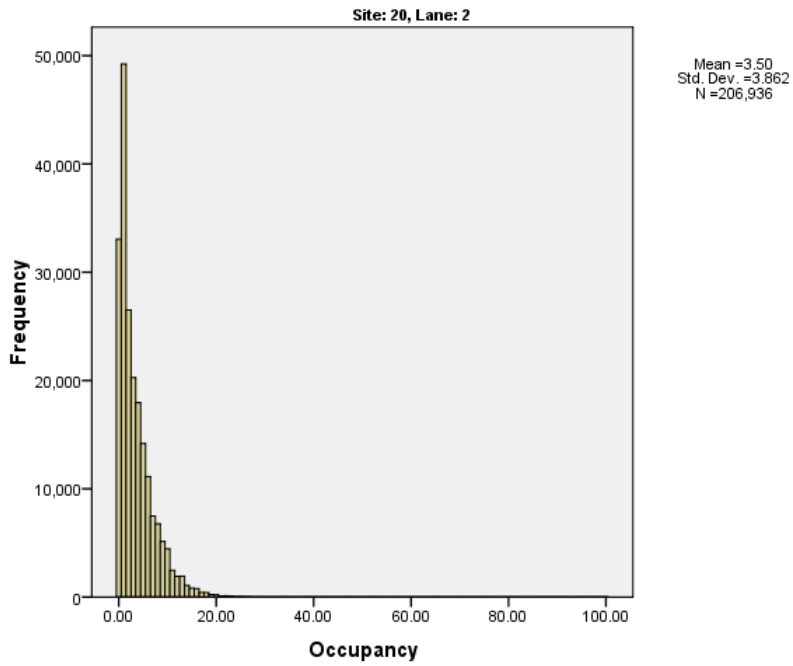


Figure 46

Histogram of occupancy for the left lane at site 20

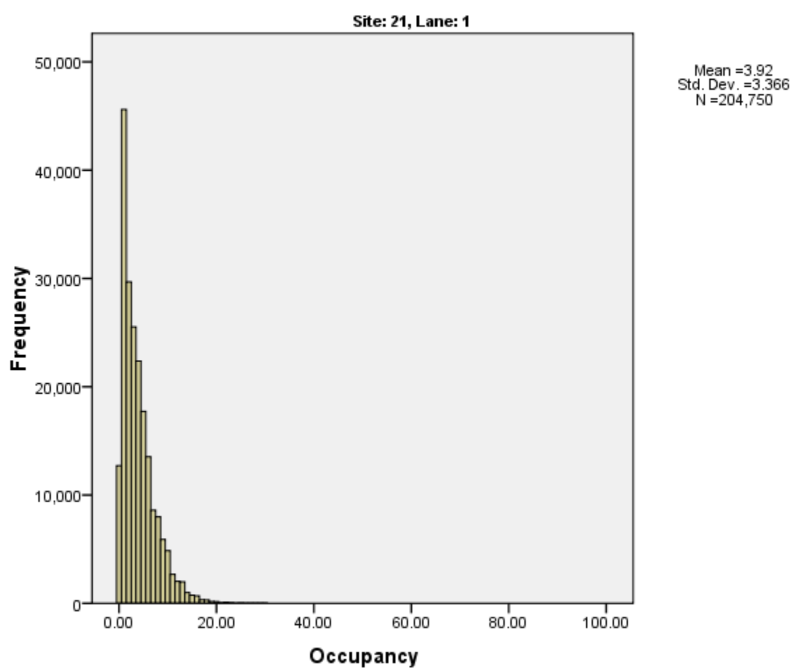


Figure 47

Histogram of occupancy for the right lane at site 21

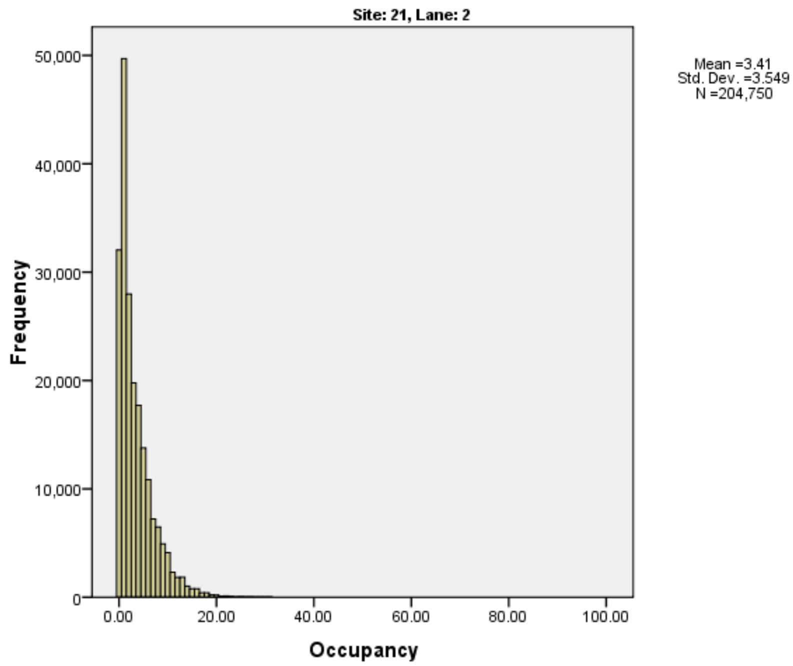


Figure 48
Histogram of occupancy for the left lane at site 21

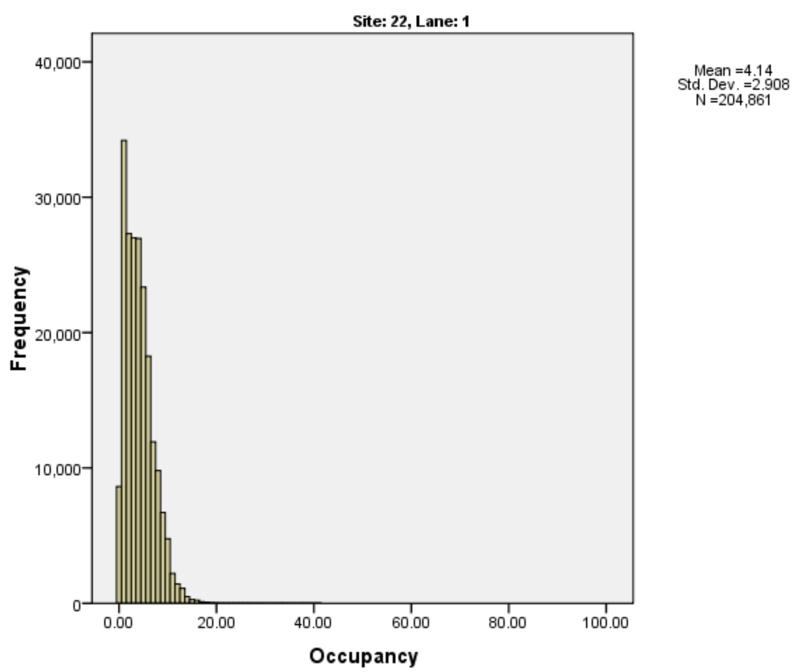


Figure 49
Histogram of occupancy for the right lane at site 22

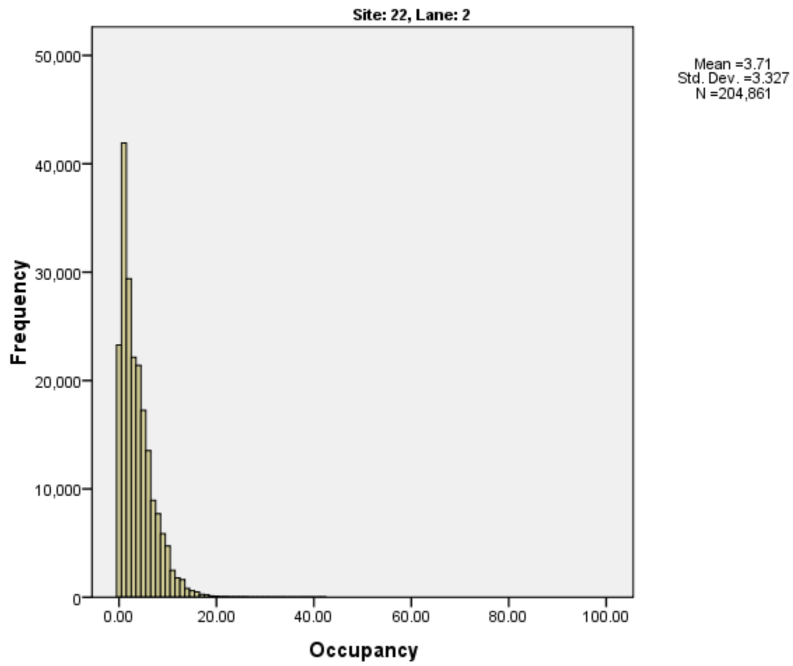


Figure 50
Histogram of occupancy for the left lane at site 22

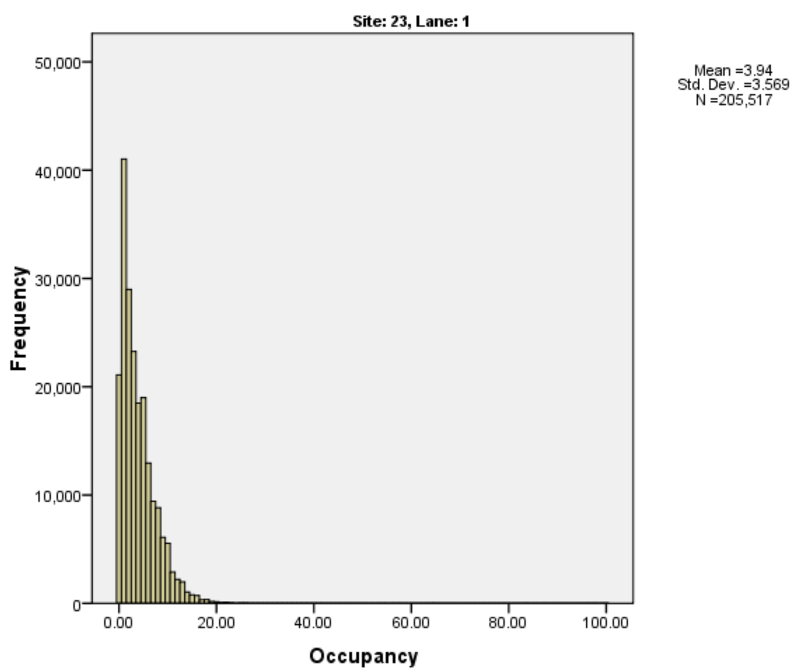


Figure 51
Histogram of occupancy for the right lane at site 23

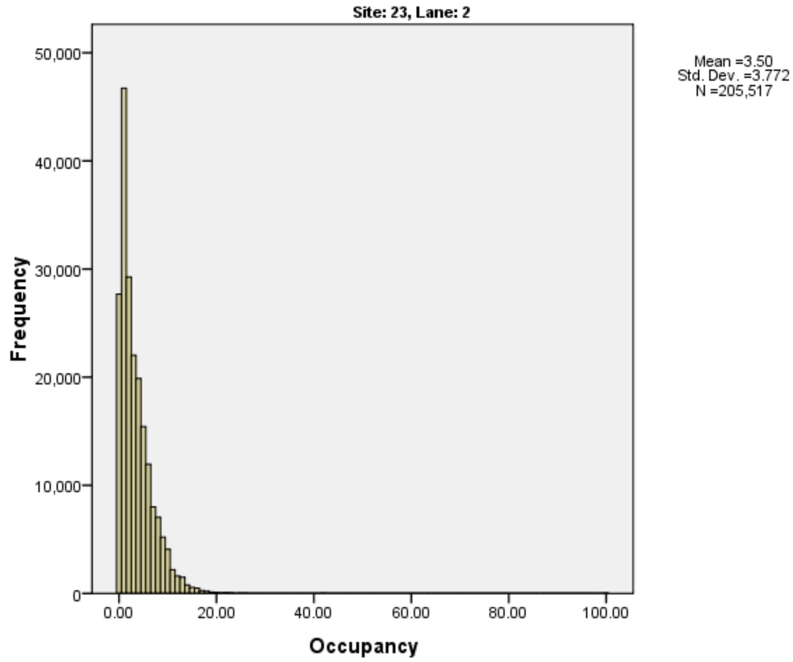


Figure 52
Histogram of occupancy for the left lane at site 23

Table 9
Basic statistics summary for lane occupancy

		Right Lane				Left Lane				overall
Site		20	21	22	23	20	21	22	23	
Mean		3.91	3.92	4.14	3.94	3.50	3.41	3.71	3.50	3.75
Standard Deviation		3.44	3.37	2.91	3.57	3.86	3.55	3.33	3.77	3.49
Quantile	100% Max	97	30	41	65	97	31	42	92	97
	99%	15	15	13	16	17	16	15	15	15
	95%	11	11	10	11	11	11	10	10	11
	90%	9	9	8	9	9	9	9	8	9
	75% Q3	6	6	6	6	6	6	6	6	6
	50% Median	4	3	4	3	3	3	3	3	3
	25% Q1	2	2	2	2	1	1	2	1	2
	10%	1	1	1	1	1	1	1	1	1
	5%	1	1	1	1	1	1	1	1	1
	1%	1	1	1	1	1	1	1	1	1
	0% Min	1	1	1	1	1	1	1	1	1

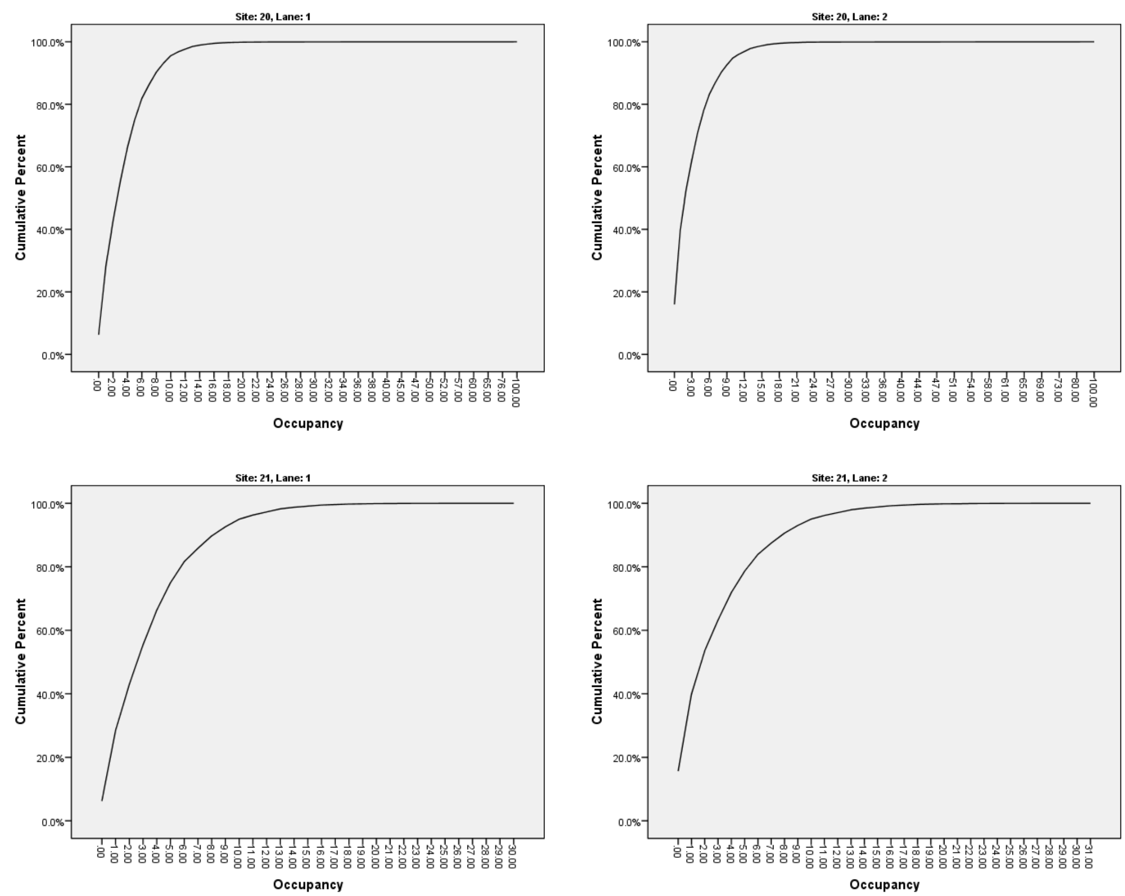


Figure 53
Cumulative distribution plots for lane occupancy at sites 20 and 21

Traffic Composition

In this study, vehicles were classified into two types: cars and trucks. This is primarily because the speed limit differential and lane restriction policies were exclusively applied to these two main categories. Based on the 30-sec. observations obtained from the RTMS units, the traffic counts are grouped into one of three categories: (1) cars only; (2) mixed cars and trucks; or (3) trucks only. The truck percentage was also calculated for each lane and site in all 30-sec. observations. Figure 55 shows the hourly distribution of trucks by lane and site. The figure shows that the average number of trucks on the right lane is consistently higher than that on the left lane for all sites. However, more trucks are observed on the left lane at sites 21 and 22 than those on the left lane at sites 20 and 23. This implies that the trucks are more compliant to lane restriction at the intermediate locations than the endpoint locations of the bridge. Passenger cars, however, tend to occupy both lanes almost equally at sites 21 and 22, as shown in Figure 56. At sites 20 and 23, passenger cars tend to use the left lane more than the right lane, possibly to avoid trucks driving at a slower speed on the right lane.

The lane distribution for passenger cars, however, tends to be more pronounced during daytime than nighttime for the intermediate locations.

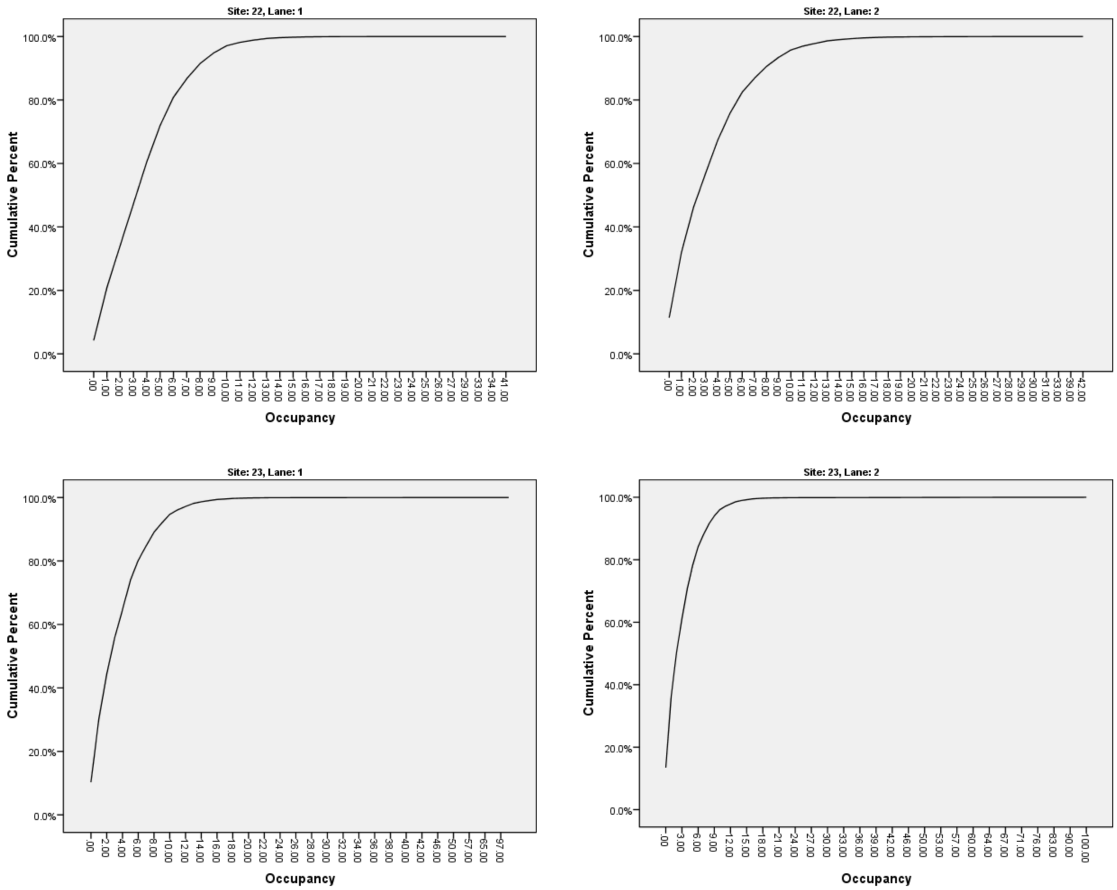


Figure 54

Cumulative distribution plots for lane occupancy at sites 22 and 23

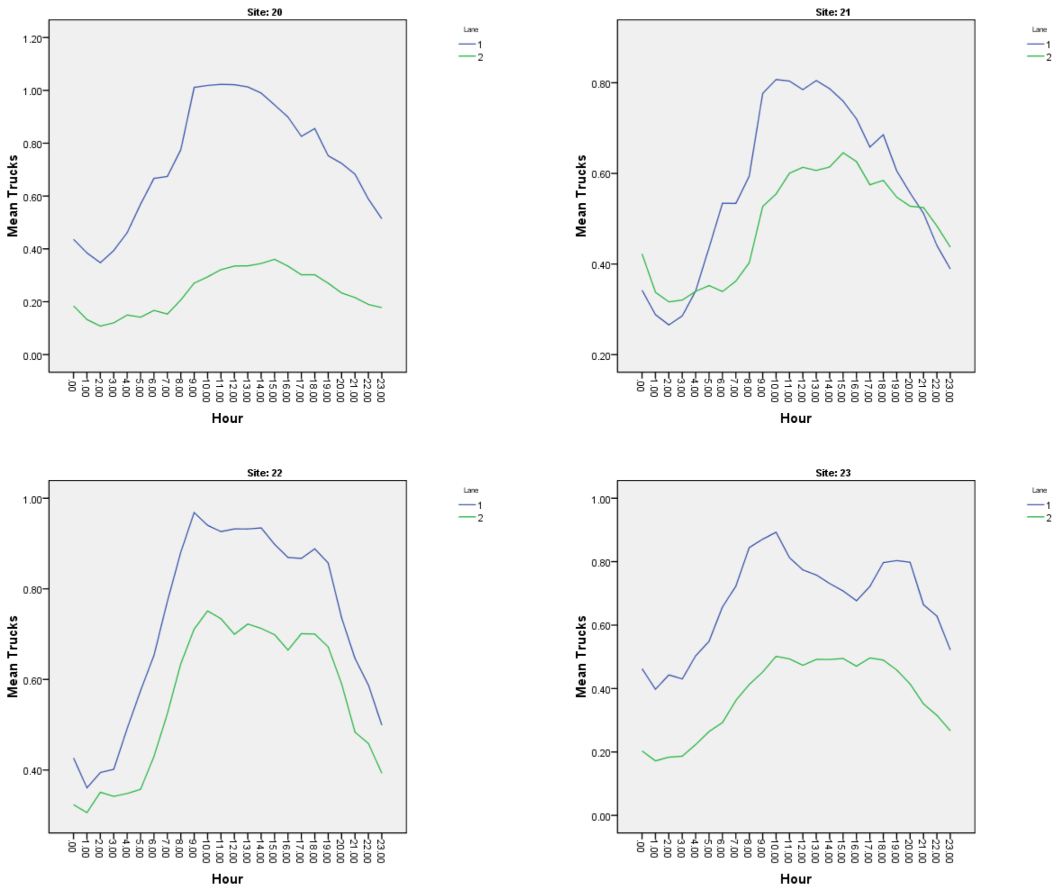


Figure 55
Average number of trucks over 30-sec. periods by lane and hour of day for each site

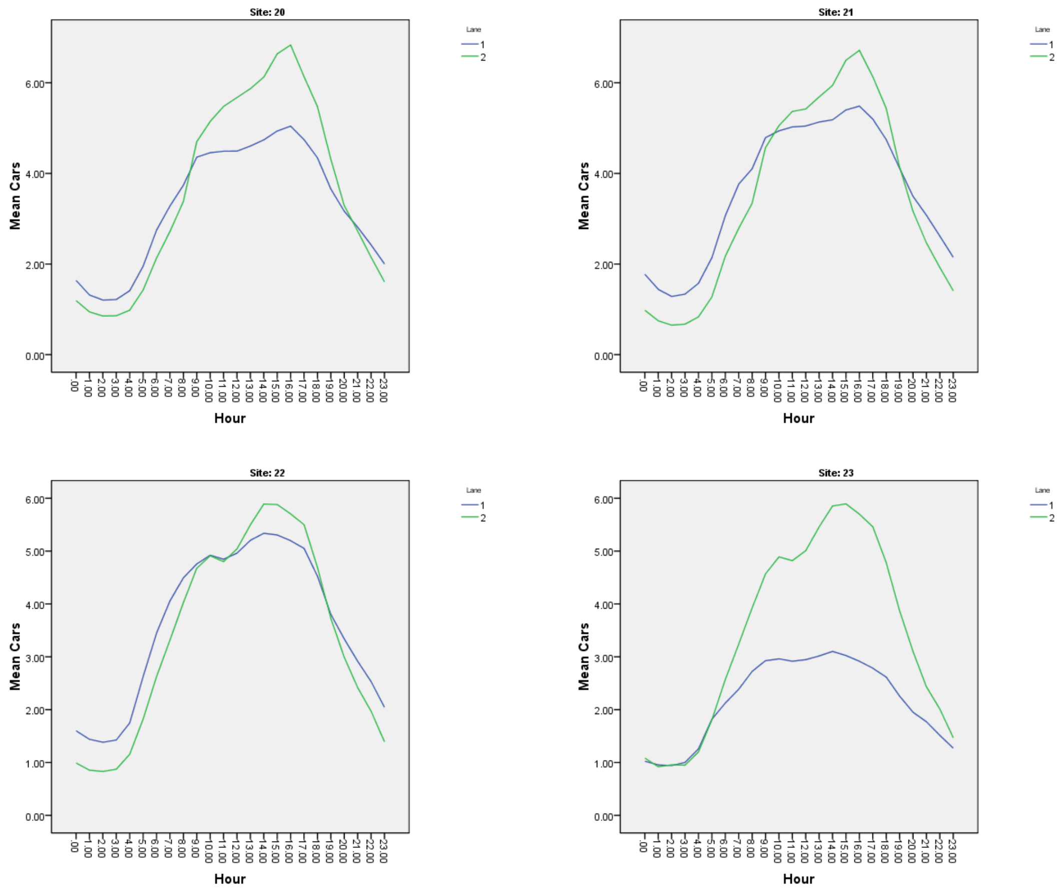


Figure 56

Average number of passenger cars over 30-sec. periods by lane and hour of day for each site

Considering the percentage of trucks in the traffic mix during 30-sec. intervals, Figure 57 shows that the right lane has a consistently higher percentage of trucks than the left lane for sites 20 and 23. The difference, however, appears to diminish for sites 21 and 22, which also show a higher percentage of trucks on the left lane during nighttime compared to daytime. Similar patterns can also be seen in Figure 58, which shows the total number of trucks observed by hour of day for each lane and site. More trucks were observed on the right lane at sites 20 and 23, which implies relatively high compliance rate to the lane restriction policy. For sites 21 and 22, the difference in the number of trucks on both lanes is relatively smaller, which implies a relatively lower compliance rate. Another possible explanation to the relatively high presence of trucks in the left lane is that trucks may also occupy the left lane for overtaking maneuvers in order to pass slower vehicles in the right lane. It is, however, impossible to distinguish between trucks occupying the left lane for passing maneuvers and those in violation of the lane restriction policy. As such, the actual violation rate may be less than that observed by the percentage of trucks in the left lane. To examine the compliance rates of trucks to lane restriction over weekdays vis-à-vis weekends, the average number of trucks was calculated for each lane and site as shown in Figure 59. In general, the same compliance behavior was observed during weekdays and weekends. For sites 21 and 22, however, the compliance rates during weekends seem to drop to nearly 50 percent as the lane distribution of trucks appears to be almost equal. Relatively lower compliance rates are also observed during weekends at sites 20 and 23, compared to weekdays.

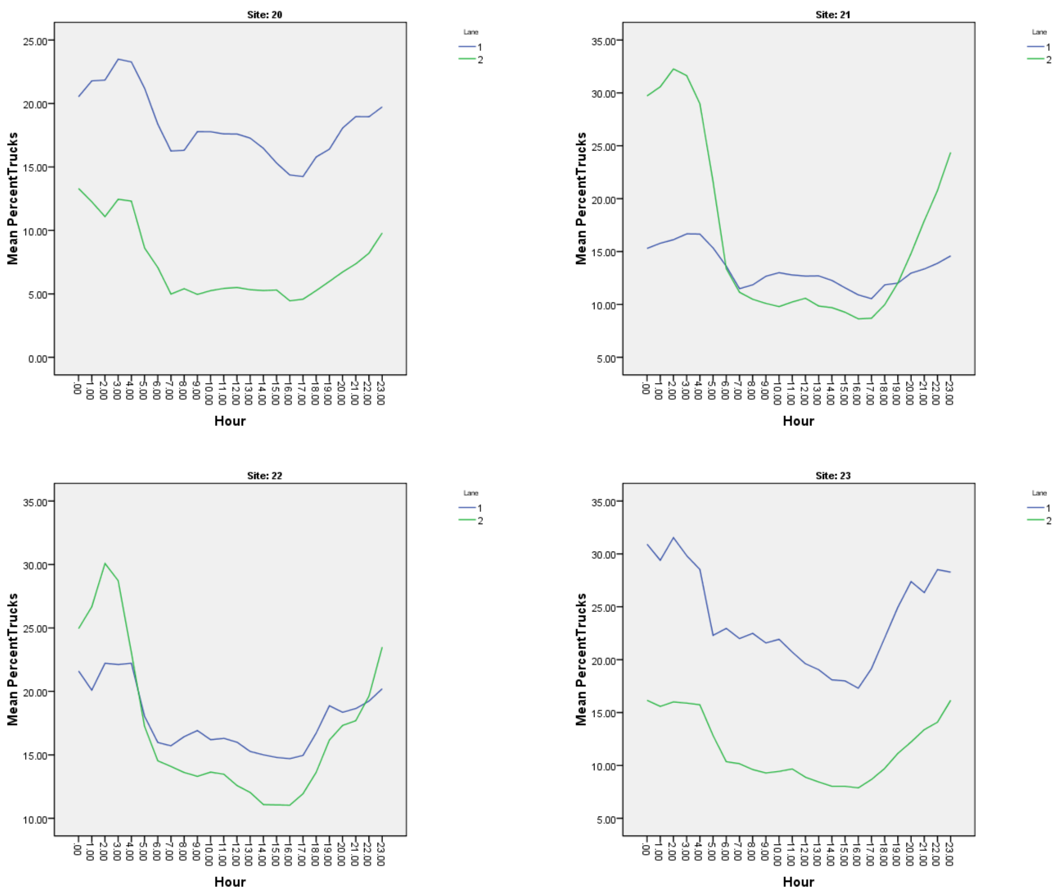


Figure 57
Mean percentage of trucks over 30-sec. periods by lane and hour of day for each site

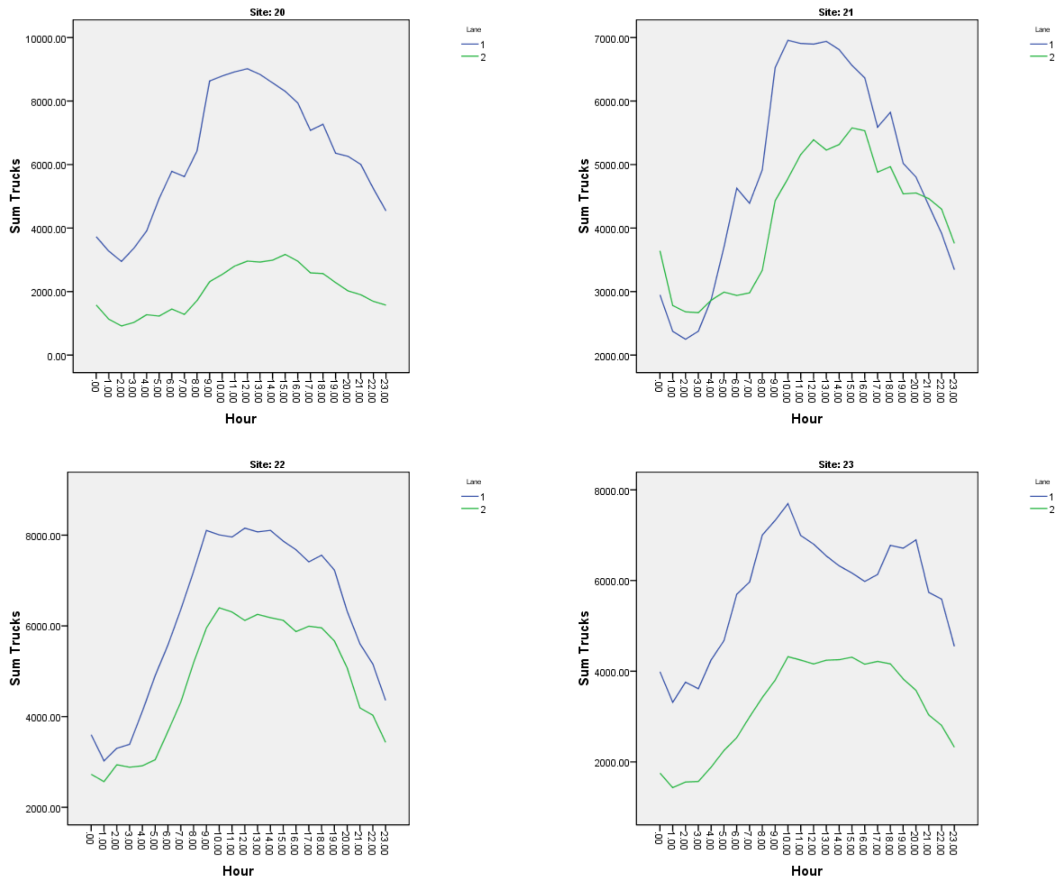


Figure 58

Number of trucks over the data collection period by lane and hour of day for each site

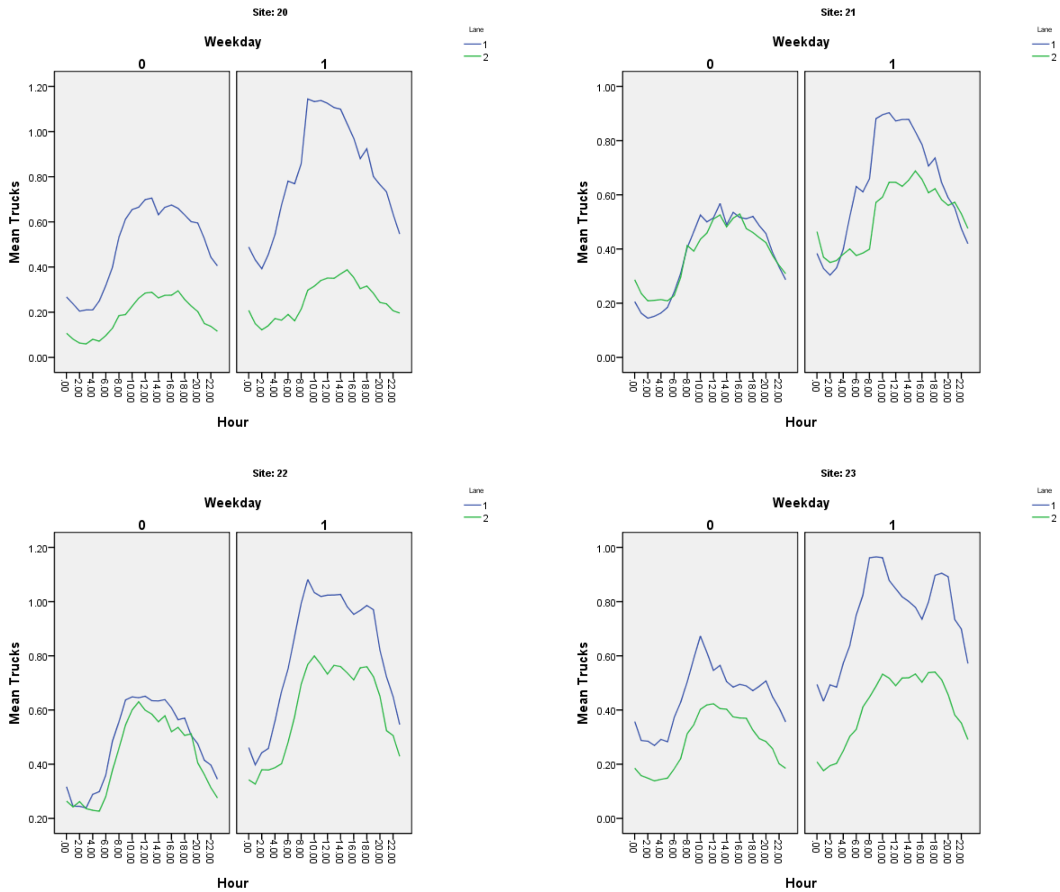


Figure 59
Average number of trucks over 30-sec. periods by lane, hour of day, and day of week (weekday = 1, weekend = 0) for each site

Linear Regression Analysis

Linear regression analysis was conducted to examine the effect of trucks on the traffic speed. First, linear models were fitted for the overall data, which was aggregated into 5-min. intervals to reduce random fluctuations in the 30-sec. observations. Then, the regression analysis was performed under different traffic conditions to remove their effects on the predicted speed. With the large number of explanatory variables in the data, a variable selection procedure was conducted to identify the most significant variables in the development of the regression models.

Variable Selection Procedure

Multiple linear regression is a common approach to investigate the effects of several independent variables on one dependent variable. In the study, the response (dependent) variable used in the linear regression model is the average speed of vehicles. The candidate explanatory variables are (1) number of trucks, (2) site, (3) lane, (4) weekday indicator, and (5) peak period indicator. The SAS

(Statistical Analysis Software) Enterprise Miner variable selection procedure was employed to screen the available explanatory variables based on the variance explanation contribution of each variable. Table 10 presents the output of the selection procedure and shows that the variables representing peak period and weekday were not significant and, therefore, were rejected as input explanatory variables. This implies that there is no apparent speed pattern on weekdays and during regular peak periods, which was expected on this rural stretch of I-10. Given the variable selection results, only "zone," "lane," and "truck volume" variables were identified as explanatory variables in the following regression analysis.

Table 10
Variable selection results

Name	Role	Rejection Reason	% Missing	Label
Zone	input		0%	zone
Lane	input		0%	nlane
Weekday indicator	rejected	Low R^2 w/ target	0%	workd
Peak hour indicator	rejected	Low R^2 w/ target	0%	rushh
Truck Volume	input		0%	svoltruck

Linear Regression Models Using All Traffic Data
Multiple linear regression models were fitted to the aggregated overall data using SAS Proc GLM (General Linear Model) procedures. The analysis was conducted to test the main and interaction term effects of the variables previously selected. The total variance explained by the model (R^2) was used to evaluate the model. In addition, the F-test statistics and T values were used to measure the significance of each term in the model. It should be noted, however, that the linear regression models developed in this section were not intended for use to predict traffic speed, but rather to examine the effect of the presence of trucks on the traffic stream speed. Therefore, the F statistic value, p value, and parameter coefficients for truck volume/truck proportion and other individual terms are of more value than the overall correlation coefficient of the linear model in the study.

Model 1: Using "Zone," "Lane," and "Truck Volume" Variables
A model using the selected variables "zone," "lane," and "truck volume" was initially fitted to capture the effect of the three variables and their interactions on the average speed. The R^2 obtained from Proc GLM procedure was 0.60, which appears to imply a relatively acceptable fit and explanation of the speed variation by the three variables. The F test results for each main and interaction term are presented in Table 11, which shows significant effects of all terms in the model. This implies that there is a significant difference in the observed speed among the four sites and between the right and left lanes at each site. Also, the truck volume has a significant impact on the average speed, which suggests that the traffic speed vary substantially with the change of truck

volume in the traffic mix. As described in previous section, the right lane has a larger truck volume but lower traffic speed, which indicates that the effect of truck volume has a negative effect on traffic speed.

Table 11
F test results for model 1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
zone	3	112403.6	37467.87	2553.75	<.0001
lane	1	3607.23	3607.23	245.86	<.0001
voltruck	1	30864.37	30864.37	2103.67	<.0001
zone*lane	3	809981.5	269993.8	18402.4	<.0001
voltruck*zone	3	16634.52	5544.84	377.93	<.0001
voltruck*lane	1	1169.3	1169.3	79.7	<.0001
voltruck*zone*lane	3	3635.38	1211.79	82.59	<.0001

Note: voltruck= truck volume

Model 2: Incorporating "Total Volume" Variable
In the study, the response (dependent) variable used in the linear regression model is the average speed of vehicles, which may not only be affected by the truck volume, but also the overall the traffic volume. Model 1, which was presented in the previous section, only accounts for the truck volume, which may not adequately explain all the variation in traffic speed. To address this issue, the total traffic volume was added as an independent variable in the regression analysis and the same SAS Proc GLM procedure was performed to fit the linear model. The results show that the addition of the total volume term led to a slight increase in R^2 (0.63). Table 12 presents the F test results for each main and interaction term in the model. The table confirms the significant impacts of the variables "zone," "lane," and "truck volume" on the traffic speed as previously concluded from Model 1. Significant results were obtained for the total volume term and all the interaction terms containing total volume, which implies that the total volume is not redundant for the linear model. While the P-values show that all total volume terms are significant, the F statistics values vary substantially. Since a large F value indicates even more significant impact of the associated term on the response variable, the "total volume," "total volume * lane," and "truck volume * total volume" terms were selected for further investigation. The significant "total volume" term implies that the traffic speed changes substantially with the change of the total volume, while the significant "total volume * lane" interaction term means the effect of total volume on traffic speed is significantly different between the right and left lanes. Special attention should be paid to the interaction term of "total volume* truck volume." The significant result implies that the effect of truck volume on traffic speed is not consistent at different levels of total traffic volume. To account for the truck

volume and its total traffic volume simultaneously, the two variables were combined and substituted with the truck percentage in the regression analysis as presented next.

Table 12
F test results for model 2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Zone	3	29420.42	9806.81	722.31	<.0001
Lane	1	1163.55	1163.55	85.70	<.0001
voltruck	1	57848.38	57848.38	4260.74	<.0001
svolume	1	10224.27	10224.27	753.05	<.0001
zone*lane	3	166883.60	55627.87	4097.20	<.0001
voltruck*zone	3	6347.08	2115.69	155.83	<.0001
svolume*zone	3	425.96	141.99	10.46	<.0001
voltruck*lane	1	509.04	509.04	37.49	<.0001
svolume*lane	1	14652.20	14652.20	1079.19	<.0001
voltruck*svolume	1	15499.49	15499.49	1141.59	<.0001
voltruck*zone*lane	3	4072.84	1357.62	99.99	<.0001
svolume*zone*lane	3	15140.07	5046.69	371.71	<.0001
voltruck*svolume*zone	3	2835.57	945.19	69.62	<.0001
voltruck*svolume*lane	1	914.75	914.75	67.37	<.0001
voltruck*svolume*zone*lane	3	283.40	94.47	6.96	<.0001

Note: voltruck= truck volume; Svolume= total volume.

Linear Regression with Controlled Traffic Condition

The regression models developed in the previous section did not account for the traffic conditions, which may also have an impact on the overall traffic speed. This typically occurs when the traffic flow rate increases and the traffic stream speed decreases as a result of the interaction between vehicles. In order to account for the effect of traffic conditions on traffic speed, another set of regression models was fitted to the data with controlled traffic conditions. The Proc REG procedure was employed to perform the regression analysis instead of Proc GLM in order to obtain the regression coefficients for each variable. Moreover, the percentage of trucks in the total volume was used as an explanatory variable in the regression analysis to replace the number of trucks, as explained earlier. The F statistic value and p value were used to determine if the trucks have a significant effect on speed. Also, the regression coefficients were used to examine if the effect was positive or negative. For this analysis, the raw 30-sec. data was used to capture more variation in the traffic data.

The lane occupancy data were used to define the traffic conditions for each 30-sec. observation. Low lane occupancy values indicate free-flow conditions, while high values indicate congested conditions. Since lane occupancy is based on the percentage of time the detector is occupied by passing vehicles over 30 sec., the values ranged from 0 to 100 percent. Table 13 shows the quantiles of lane occupancy data observed at all sites and lanes during the data collection period. The table shows that nearly 95 percent of the observations did not exceed 11 percent. In other words, the study section operated most of the time under steady state traffic conditions, which are expected to prevail at rural freeway sections. To account for the slightly different traffic conditions, the range of lane occupancy values was divided into 12 groups as shown in Table 14. Since only 5 percent of the observations exceeded 11 percent, a cut-off value of 11 percent was used to group all observations above this value into one category.

Regression Model with Main Effects of Zone, Lane, and Truck Percentage

A regression model with only the main effect terms of “zone,” “lane,” and “percentage of trucks” was fitted initially. To include categorical variables in the Proc REG procedure, one dummy variable “lane” was used to represent the lane (1 for the right lane and 0 for the left lane) and three dummy variables “zone 1,” “zone 2,” and “zone 3” were used to designate the site as shown in Table 15.

Table 13

Quantiles of lane occupancy

Quantile	Occupancy
100% Max	97
99%	15
95%	11
90%	9
75% Q3	6
50% Median	3
25% Q1	2
10%	1
5%	1
1%	1
0% Min	1

Table 14

Lane occupancy groups

Group	Lane Occupancy (%)
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	>11

Table 15

Dummy variables for zones

Site	Zone1	Zone2	Zone3
20	1	0	0
21	0	1	0
22	0	0	1
23	0	0	0

The regression model takes the form:

$$Speed=\beta_0+\beta_1*Zone1+\beta_2*Zone2+\beta_3*Zone3+\beta_4*Lane+\beta_5*ptruck \quad (3)$$

where, ptruck = truck percentage.

The results of the regression analysis, shown in Table 16, indicate that all independent variables in the model are significant for all lane occupancy groups considered. The regression coefficients represent the effect of the unit change of each independent variable on the average speed. The table shows that the average traffic speeds at zone 3 (site 22) are the highest among all four sites. Zone 1 (site 20) appears to have the lowest traffic speed. The negative parameters associated with the variable "lane" imply that the speed at the right lane is generally 7-8 mph lower than it is on the left lane. This difference in speed between the two lanes is also significant, which confirms earlier observations. The results also show that the coefficients of the truck percentage variable are positive, which suggest that the overall traffic speed tends to increase with a higher percentage of trucks. This may appear contradictory to the results obtained earlier and can be attributed to the absence of interaction terms in this model, especially between the “lane” and “truck percentage” variables. An alternative explanation is that higher truck percentages are experienced in off-peak periods (e.g., at night) when higher speeds are achieved. This is verified by the increasing coefficient value for ptruck with increasing lane occupancy group. In essence, a high correlation between the variable “lane” and the “truck percentage” is expected since more trucks tend to use the right lane because of the imposed lane restriction. To examine the effect of the percentage of trucks exclusively on the average traffic speed, the zone and lane variables were excluded from the regression model as presented next.

Table 16
Model parameters with only main effects of site, lane, and truck percentage

Variable	Parameter	Lane Occupancy Group											
		1	2	3	4	5	6	7	8	9	10	11	12
	β0	65.30	65.32	65.43	65.63	65.50	65.59	65.60	65.51	65.68	65.35	65.36	62.97
Zone1	β1	-0.44	-0.66	-0.91	-1.21	-1.05	-1.24	-1.18	-1.09	-1.33	-1.03	-1.05	-0.10
Zone2	β2	1.14	1.14	1.12	0.73	0.92	0.66	0.57	0.68	0.32	0.43	0.31	1.26
Zone3	β3	3.43	3.66	3.72	3.48	3.68	3.49	3.48	3.50	3.10	3.24	3.12	4.07
Lane	β4	-7.45	-7.62	-7.76	-7.74	-7.90	-7.99	-8.22	-8.36	-8.42	-8.49	-8.69	-8.60
ptruck	β5	0.95	0.37	0.74	0.93	0.79	1.34	1.52	1.68	2.01	2.18	2.72	5.02

Regression Model with Main Effect of Truck Percentage Only

To capture the main overall effect of truck percentage on the traffic speed, a linear regression model with only the main effect of truck percentage for each lane occupancy group was fitted using Proc REG (Regression) procedure in the form:

$$\text{Speed}=\beta_0+\beta_1*\text{ptruck} \qquad (4)$$

where, ptruck = truck percentage.

The parameters of the model are presented in Table 17 for all 12 levels of lane occupancy. Except for the 1 percent and 2 percent occupancy levels, the model parameters were negative, which indicates that the truck percentage has an adverse impact on the overall traffic speed. In other words, trucks appear to have lower speeds than the rest of the traffic stream, which can be attributed to the lower speed limit imposed on trucks. This suggests that trucks are generally compliant to the speed limit. To examine the compliance behavior further, the interaction terms will be incorporated into the regression model as presented next.

Table 17
Model parameters with main effect of truck percentage only

Parameter	Lane Occupancy Group											
	1	2	3	4	5	6	7	8	9	10	11	12
$\beta 0$	62.89	62.55	62.46	62.42	62.75	62.85	63.11	63.27	63.64	63.69	63.93	63.07
$\beta 1$	3.74	0.63	-0.48	-0.58	-2.51	-2.53	-3.90	-4.91	-5.95	-6.71	-7.13	-6.54

Regression Model Incorporating Two-Way Interaction Terms

This section presents a regression model with all interaction terms between the three traffic variables: zone, lane, and truck percentage. The Proc REG procedure was used to fit a regression model in the form:

$$\text{Speed}=\beta_0+\beta_1\text{*Zone1}+\beta_2\text{*Zone2}+\beta_3\text{*Zone3}+\beta_4\text{*Lane}+\beta_5\text{*Ptruck}+\beta_6\text{*Ptruck*Zone1}+\beta_7\text{*Ptruck*Zone2}+\beta_8\text{*Ptruck*Zone3}+\beta_9\text{*Ptruck*Lane} \quad (5)$$

Table 18 shows the coefficients of the regression model for all levels of lane occupancy. Cells marked with * indicate variables that were not statistically significant at 0.05. In order to illustrate the variation of traffic speed with the explanatory variables, estimates of traffic speed were calculated using the fitted regression model. Three categories of truck percentages were assumed at 0 percent, 50 percent and 100 percent to represent conditions with passenger cars only, mixed cars and trucks, and trucks only, respectively. The predicted traffic speed from the model at all levels of lane occupancy for sites and lanes are presented in Figure 60 (0 percent trucks), Figure 61 (50 percent trucks), and Figure 62 (100 percent trucks).

Figure 60 shows the average predicted speed by site and lane for different occupancy levels and no trucks. The figure clearly shows that the left lanes at all sites have substantially higher speed than the right lanes. This observation is intuitive as slower traffic tends to stay on the right lane, although the speed limit for passenger cars is the same for both lanes. Also, the average speed seems to slightly decrease as the lane occupancy increases, but more noticeably beyond the 10 percent occupancy level, when the interaction between vehicles begins to influence the speed of vehicles. Similar trends are observed in Figure 61, where the percentage of trucks increases to 50 percent in the traffic mix. The speed on the right lane seems to be consistently lower than it is on the left lane.

Table 18
Parameter estimates of full model

Parameter	Traffic condition category											
	1	2	3	4	5	6	7	8	9	10	11	12
β0	65.27	65.36	65.53	65.69	65.81	65.83	66.00	66.08	66.31	66.12	66.17	63.47
β1	-0.42	-0.72	-0.85	-1.05	-1.03	-0.93	-0.84	-0.77	-0.83	-0.49	-0.36	1.29
β2	1.16	1.11	0.90	0.60	0.29	0.06*	-0.39	-0.56	-1.25	-1.41	-1.67	-0.60
β3	3.49	3.67	3.61	3.48	3.26	3.15	3.01	2.76	2.27	2.24	2.13	3.95
β4	-7.45	-7.67	-7.81	-7.89	-8.03	-8.17	-8.53	-8.78	-8.88	-9.14	-9.51	-9.78
β5	2.32	0.10*	-0.17*	0.27	-1.24	-0.49	-1.27	-1.84	-1.82	-2.26	-1.95	1.50
β6	-1.33	0.44	-0.62	-1.15	-0.59	-1.99	-2.07	-1.92	-2.64	-2.75	-3.42	-5.92
β7	-1.44	0.22	1.72	1.02	3.54	3.38	5.04	5.99	7.29	8.08	8.43	7.33
β8	-2.09	0.03*	0.80	0.18*	2.10	1.81	2.34	3.35	3.64	4.17	3.99	0.92*
β9	-0.26*	0.26	0.73	1.17	1.37	1.69	2.45	2.92	3.15	3.88	4.51	5.42

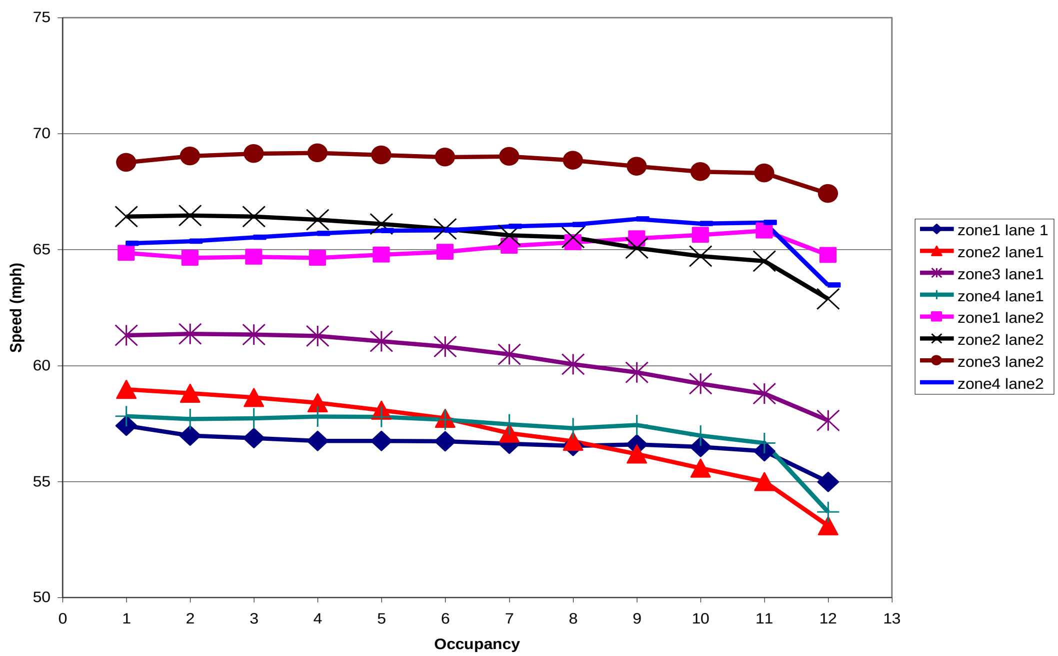


Figure 60
Estimated speed vs. occupancy (truck percentage = 0 percent, lane 1 = right lane, lane 2 = left lane)

Figure 62 shows the predicted speed by site and lane when the traffic composition is 100 percent trucks. For two of the four sites, the speed on the right lane falls between 55 and 60 mph and between 60 and 65 mph on the right lane of the other two sites. For all sites, however, the speed on the right lane is consistently lower than it is on the left lane. It should be noted that the predicted speed in Figure 62 reflects the actual speed of trucks since this case represents traffic observations with 100 percent trucks. As such, the results indicate that while trucks are restricted to the right lane at a speed limit of 55 mph, they appear to exceed the posted speed limit as well as use the left lane despite the imposed lane restriction. Moreover, trucks that violate the lane restriction policy by driving on the left lane tend to drive even faster than those on the right lane. This behavior is more likely to be observed during nighttime when enforcement is less strictly applied.

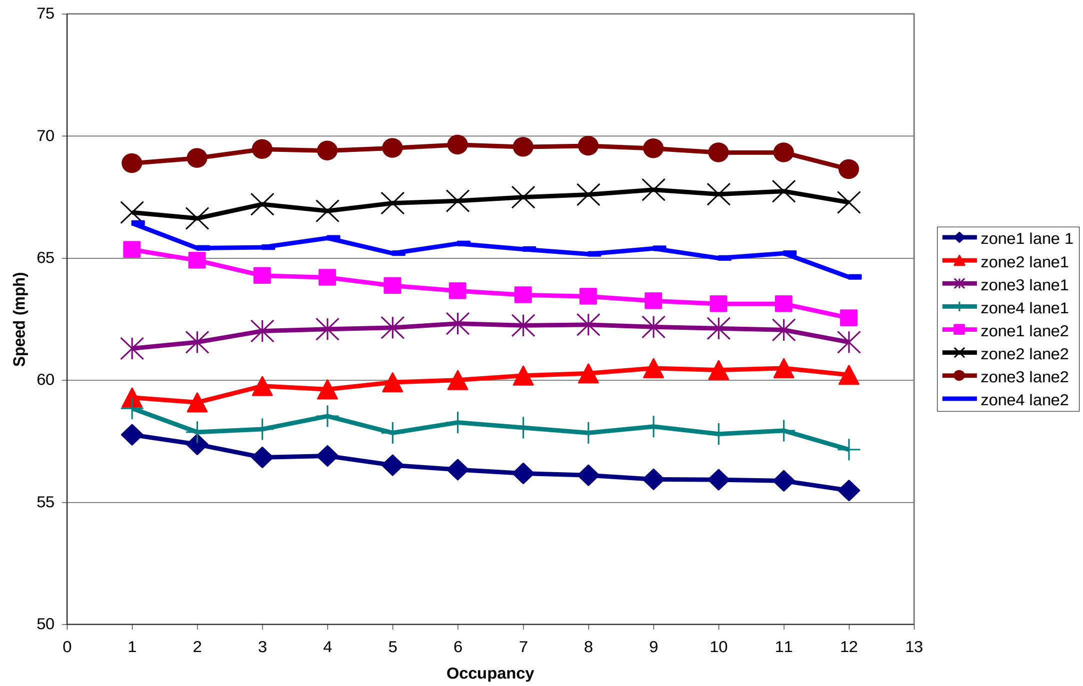


Figure 61
Estimated speed vs. occupancy (truck percentage = 50 percent, lane 1 = right lane, lane 2 = left lane)

Pairwise Comparison

The speed measurements in the raw dataset are the average speeds of all vehicles passing over the RTMS detectors in 30-sec. periods. Since vehicles were grouped into two classes (passenger cars and trucks) in the study, the traffic composition can be broken down into three groups, namely cars only, mixed cars and trucks, and trucks only. Under mixed vehicle conditions, the average speed is derived from equation (6) in which the passenger car speed and truck speed are unknown since the RTMS devices do not collect individual vehicle speeds. As such, the average truck speed cannot be estimated from the average speed unless the average passenger car speed is also known. In order to estimate the average truck speed under mixed conditions, an assumption must be made to estimate the average passenger car speed. For such conditions, the passenger car speed distribution under mixed condition was assumed to be similar to speed distribution under the cars only condition when free-flow conditions prevail.

$$S = (1 - P_T) * S_C + P_T * S_T \quad (6)$$

where,

S = average speed for all vehicles;

P_T = proportion of trucks in total volume;

S_C = average speed of cars; and

S_T = average speed of trucks.

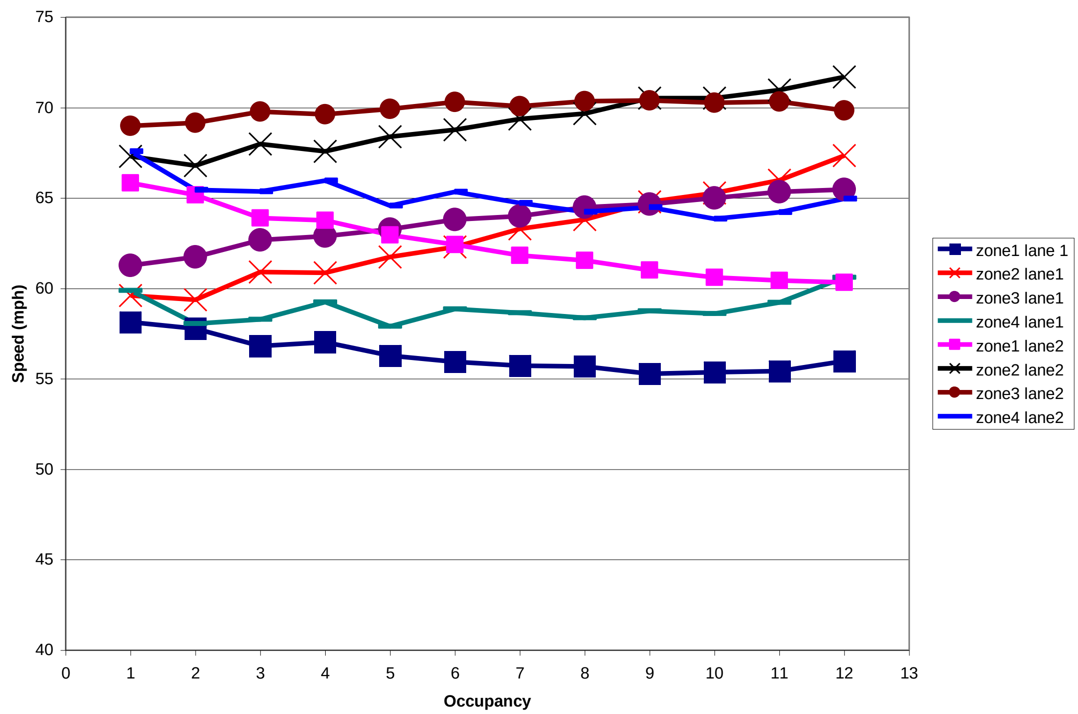


Figure 62

Estimated Speed vs. occupancy (truck percentage=100 percent, lane 1 = right lane, lane 2 =left lane)

To substitute the speed of cars under cars only condition into equation (6), another assumption was made that car speed fluctuated around its mean with the same deviation as the average speed under mixed condition in terms of standard deviation such that:

$$\frac{(S-\mu_1)}{\sigma_1} = \frac{(S_C-\mu_2)}{\sigma_2} \tag{7}$$

where,
S = average speed of all vehicles under mixed conditions;
μ_1 = mean of average speed of all vehicles under mixed conditions;
σ_1 = standard deviation of average speed of all vehicles under mixed conditions;
S_C = speed of cars under mixed condition;
μ_2 = mean of speed of cars under cars only condition; and
σ_2 = standard deviation of cars under cars only conditions.

Equations (6) and (7) were used to calculate the truck speed for each 30-sec. record. Based on the assumptions, only the traffic data under free flow condition were selected for the truck speeds calculation. First, car speed for each 30-sec. interval was obtained through rearrangement of equation (7),

$$S_c = \frac{(S-\mu_1)}{\sigma_1}\sigma_2 + \boldsymbol{\mu_2} \tag{8}$$

where,
S_C = speed of card under mixed conditions for a 30-sec. interval;
S = average speed of all vehicles under mixed conditions for a 30-sec. interval;
μ_1 = mean of average speed of all vehicles under mixed condition for all 30-sec. records; and
σ_1 = standard deviation of average speed of all vehicles under mixed condition for all 30-sec. records;
μ_2 = mean of speed of cars under cars only condition for all 30-sec. records; and
σ_2 = standard deviation of cars under cars only conditions for all 30-sec. records.

Then, the truck speed for each 30-sec. interval was calculated by substitute S_c into equation (6),

$$S_T = \frac{S-(1-P_T)*S_C}{P_T} \tag{9}$$

where,
S_T = average speed of trucks under mixed condition for a 30-sec. interval;
S = average speed for all vehicles under mixed condition for a 30-sec. interval;
P_T = proportion of trucks in total volume under mixed condition for a 30-sec. interval; and

S_C = average speed of cars under mixed condition for a 30-sec. interval.

After the truck speeds under the mixed condition were calculated, Tukey adjustment was used to compare car speed, truck speed under mixed conditions, and truck speed under trucks only condition. In addition, the speeds of cars and trucks were compared to the corresponding speed limits using T-tests to examine the compliance to the differential speed limit. The data for different lanes and different sites were analyzed separately to show the effect of site and lane in the results.

In the study, data with occupancy less than 12 percent were considered under free flow condition and used for the pairwise comparison. To verify this, the truck volumes were converted into passenger car volume and the equivalent passenger car volume of every 30 sec. were calculated, where the mid-sized vehicle was counted as 1.2 passenger cars, the long truck was 1.5 passenger car, and the extra-long-truck was 2.0 passenger cars. It is known that the free flow condition is the traffic condition where the rate of flow is less than 1300 vehicles/hour/lane, which is equivalent to 10.8 vehicles/lane/30 sec. The data with occupancy less than 12 percent were selected from the raw dataset, and their equivalent passenger car volume was compared to 10.8 vehicles/lane/30 sec. No equivalent 30-sec. volumes were larger than 10.8, which prove that the data with occupancy less than 12 is under free flow condition.

Pairwise Comparison of Traffic Speeds

The calculated average truck speed under mixed traffic composition condition on both lanes at different sites are presented in Figure 63, along with the average traffic speeds at cars only and trucks only conditions. It shows that, for all sites, the speeds under three different traffic composition conditions are lower on the right lane than on the left lane, which is consistent with the regression analysis results above. The average passenger car speeds fall between 60 and 67 mph, except for two sites (site 20 and site 23), where passenger cars traveled at posted truck speed limit (55 mph) on the right lane, even though the speed limit for passenger cars is 60 mph for both lanes. In most cases, the truck speeds are higher than the posted truck speed limit of 55 mph. Moreover, trucks drive even faster than the passenger cars when the traffic composition is 100% trucks.

To further investigate the traffic characteristics of the trucks only condition, the variation of truck volume and truck speed over time under trucks only condition was analyzed. Figure 64 presents the profile of truck volume over time, along with the number of data records when the traffic composition of 100 percent trucks. It shows that most data for trucks only condition was observed during nighttime. Also more trucks were detected during the unit time at night than at daytime. The average truck speeds over time of day are presented in Figure 65. It shows that all the hourly average truck speeds are larger than the speed limit of 55 mph. However, it should be noticed that the severe violations of the speed limit occur during nighttime.

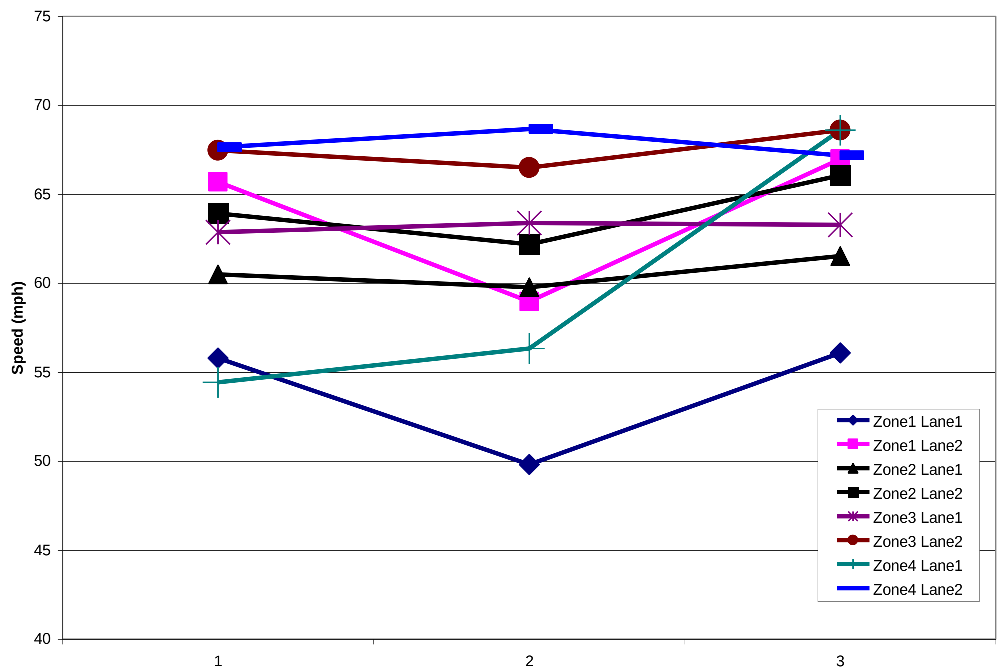


Figure 63

Average speed at different traffic composition condition

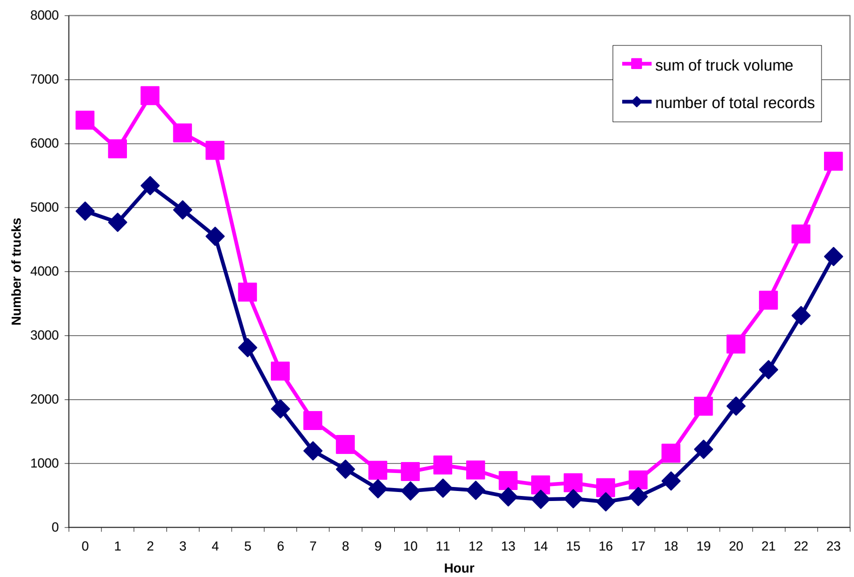


Figure 64
Number of trucks under trucks only condition

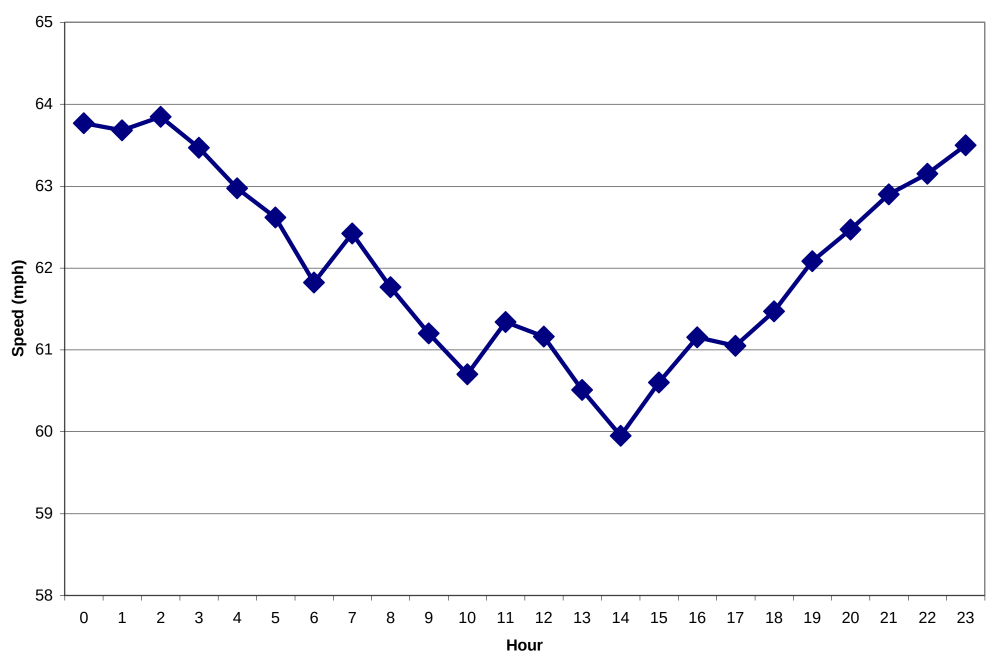


Figure 65
Hourly average truck speeds under trucks only condition

Table 19 presents the pairwise comparison results of the car speeds, truck speeds under mixed traffic composition condition, and truck speed under trucks only traffic composition condition by sites and lanes. Cells marked with * indicate the difference between the compared two speeds was not statistically significant at the 0.05 level.

Table 19
Average speed of different traffic composition condition

Comparison	Difference Between Means							
	Zone 1		Zone 2		Zone3		Zone4	
	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
1 - 2	5.99	6.71	0.73	1.74	0.41	0.96	1.91	0.45
1 - 3	-0.28	-1.28	-1.03	-2.14	-0.10*	-1.12	-0.96	-1.02
2 - 3	-6.27	-7.99	-1.76	-3.87	-0.51	-2.08	-2.87	-1.47

Note: 1: traffic speed under cars only condition;
2: speed of trucks under mixed traffic condition;
3: traffic speed under truck only condition.

Significant differences were obtained from the pairwise comparison except for one case. It shows that for all sites on both lanes trucks under trucks only conditions have the highest speeds among the three groups. This indicates that the truck drivers are more aggressive under trucks only conditions than under the mixed. Since only traffic data under free flow condition were used for the pairwise comparisons, the cars speed distribution under cars only and mixed conditions are statistically similar based on the assumption in the previous section. Therefore, the comparison 1-2 also indicates the comparison between truck speed and car speed under mixed condition. The results show that when there are both cars and trucks observed in the traffic flow, the truck speed is substantially lower than speed of cars, which indicates that the differential speed limit policy was effective somehow.

Comparison of Traffic Speeds with Speed Limits

Table 20 presents the T test results for comparison of truck speeds under mixed traffic composition condition with truck speed limit of 55 mph as well as the speeds 5 mph and 10 mph above the speed limit (60 mph and 65 mph). It shows that truck speeds under mixed traffic condition are significantly higher than the truck speed limit, except for on the right lane at site 20. Moreover, the table shows that trucks travel slower than 60 mph on the right lane, but faster than 60 mph on the left lane except at site 22 where truck speeds on both lanes are higher than 60 mph. Also, only the truck speeds on the left lane for sites 22 and 23 are higher than 65 mph. The comparison results indicate that, under mixed conditions, trucks did not strictly comply with the differential speed limit, and trucks violated the right lane restriction to travel on the left lane. However, it should be noticed that the violation of truck speed limit is not severe, since trucks travel below 65 mph, and truck speeds on the right lane are even lower than 60 mph. Also, many of the trucks observed in the left lane may have been legitimately overtaking vehicles in the right lane and would have elevated speeds during that maneuver.

Table 21 presents the T test results for comparison of truck speeds under trucks only conditions with 55 mph, 60 mph and 65 mph. It shows trucks travel significantly faster than the speed limit, and the speeds are substantially more than 5 mph above the speed limit except for on the right lane of sites 20 and 23. Compared with 65 mph, the truck speeds on the right lane are lower than the value, while the speeds on the left lanes are higher than the value. It indicates that, under trucks only condition, trucks tend to drive much faster than the speed limit, and the more severe violations were observed in the left lanes. However, it should be noticed that much less data were collected under trucks only condition compared to the mixed condition. Therefore, the severe violations of speed limit only account for a small portion of the total trucks observed.

Table 22 presents the T test results for comparison of car speeds with the 60-mph speed limit, as well as 5 mph and 10 mph above the speed limit. The results show that car speeds are generally higher than the 60-mph speed limit except on the right lanes of sites 20 and 23. On all right lanes, the car speeds were statistically lower than 65 mph. On all left lanes, except that of site 21, the car speeds exceeded 65 mph. Nevertheless, for all lanes of the four sites, passenger cars did not exceed 70 mph. In essence, the results show that passenger car speeds fell in the range of 60 to 70 mph, which could reflect a relatively good compliance to the speed limit.

Table 20

Comparison of truck speed at mixed condition with speed limit

Compared with 55 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	76549	-5.27	6.04	-241.32	<.0001
	2	28259	5.20	5.27	165.84	<.0001
21	1	63840	4.85	4.60	266.58	<.0001
	2	52012	7.64	4.67	373.26	<.0001
22	1	86628	8.44	4.24	585.46	<.0001
	2	65436	11.60	4.48	662.26	<.0001
23	1	68306	1.44	4.09	91.83	<.0001
	2	48010	13.78	4.05	745.94	<.0001
Compared with 60 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	76549	-10.27	6.04	-470.23	<.0001
	2	28259	0.20	5.27	6.30	<.0001
21	1	63840	-0.15	4.60	-8.04	<.0001
	2	52012	2.64	4.67	128.84	<.0001
22	1	86628	3.44	4.24	238.57	<.0001
	2	65436	6.60	4.48	376.92	<.0001
23	1	68306	-3.56	4.09	-227.61	<.0001
	2	48010	8.78	4.05	475.34	<.0001
Compared with 65 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	76549	-15.27	6.04	-699.13	<.0001
	2	28259	-4.80	5.27	-153.23	<.0001
21	1	63840	-5.15	4.60	-282.67	<.0001
	2	52012	-2.36	4.67	-115.58	<.0001
22	1	86628	-1.56	4.24	-108.32	<.0001
	2	65436	1.60	4.48	91.57	<.0001
23	1	68306	-8.56	4.09	-547.04	<.0001
	2	48010	3.78	4.05	204.74	<.0001

Table 21

Comparison of truck speed at trucks only condition with speed limit

Compared with 55 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	4050	1.13	4.07	17.70	<.0001
	2	3148	11.98	4.00	167.95	<.0001
21	1	3753	6.54	3.45	116.16	<.0001
	2	8420	11.06	4.30	235.94	<.0001
22	1	4048	8.29	4.36	120.99	<.0001
	2	8121	13.60	4.14	295.75	<.0001
23	1	12949	2.29	3.90	67.00	<.0001
	2	5093	12.21	4.06	214.69	<.0001
Compared with 60 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	4050	-3.87	4.07	-60.49	<.0001
	2	3148	6.98	4.00	97.87	<.0001
21	1	3753	1.54	3.45	27.30	<.0001
	2	8420	6.06	4.30	129.30	<.0001
22	1	4048	3.29	4.36	48.03	<.0001
	2	8121	8.60	4.14	187.02	<.0001
23	1	12949	-2.71	3.90	-78.99	<.0001
	2	5093	7.21	4.06	126.79	<.0001
Compared with 65 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	4050	-8.87	4.07	-138.67	<.0001
	2	3148	1.98	4.00	27.78	<.0001
21	1	3753	-3.46	3.45	-61.56	<.0001
	2	8420	1.06	4.30	22.65	<.0001
22	1	4048	-1.71	4.36	-24.94	<.0001
	2	8121	3.60	4.14	78.28	<.0001
23	1	12949	-7.71	3.90	-224.98	<.0001
	2	5093	2.21	4.06	38.89	<.0001

Table 22
Comparison of car speed with speed limit

Compared with 60 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	79893	-4.17	3.42	-344.93	<.0001
	2	127283	5.72	4.22	483.29	<.0001
21	1	113734	0.51	4.00	43.17	<.0001
	2	101398	3.95	4.19	300.44	<.0001
22	1	80884	2.87	4.08	200.40	<.0001
	2	95631	7.48	4.34	533.02	<.0001
23	1	92104	-5.57	4.79	-354.36	<.0001
	2	115777	7.72	4.42	593.69	<.0001
Compared with 65 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	79893	-9.17	3.42	-758.06	<.0001
	2	127283	0.72	4.22	60.76	<.0001
21	1	113734	-4.49	4.00	-377.91	<.0001
	2	101398	-1.05	4.19	-79.59	<.0001
22	1	80884	-2.13	4.08	-148.17	<.0001
	2	95631	2.48	4.34	176.57	<.0001
23	1	92104	-10.51	4.66	-684.14	<.0001
	2	115777	2.72	4.42	209.03	<.0001
Compared with 70 mph						
Site	Lane	N	Mean	Std Dev	t Value	Pr > |t|
20	1	79893	-14.17	3.42	-1171.20	<.0001
	2	127283	-4.28	4.22	-361.78	<.0001
21	1	113734	-9.49	4.00	-798.99	<.0001
	2	113734	-9.49	4.00	-798.99	<.0001
22	1	80884	-7.13	4.08	-496.73	<.0001
	2	95631	-2.52	4.34	-179.89	<.0001
23	1	92104	-15.51	4.66	-1009.50	<.0001
	2	115777	-2.28	4.42	-175.63	<.0001

Summary

In the study, the traffic data of both right lane and left lane at four sites on Atchafalaya I-10 segment were collected. Based on the collected data, the travel behavior of tucks was investigated, and their effect on the traffic speed was analyzed individually and jointly with variables “zone” and “lane” at different conditions. In addition, the speed of trucks at mixed traffic conditions was calculated and compared with the speed under cars only and trucks only conditions and speed limit as well.

It was found that the number of trucks traveled on the right lane is significantly higher than those on the left lane, which indicates that most of trucks complied with the right lane restriction policy.

However, it was noticed that there were still a considerable number of trucks that traveled on the left lane. As mentioned earlier, a possible explanation for the presence of trucks in the left lane is for passing maneuvers, which is permissible on that section. As such, it is difficult to accurately determine the actual compliance rate for lane restriction. At minimum, the estimated compliance rate was in the range of 60 percent to 80 percent most of the time, which could be even higher if the left lane is strictly used for passing maneuvers only. This situation needs to be seen in the context that truckers were instructed that it was permissible to overtake in the left lane, so some observations of trucks in the left lane did not reflect non-compliance but merely a temporary legitimate maneuver of the truck. The regression analysis shows that the trucks have significant effect on the traffic speed at all zones and lanes, and the speed decreases with the increase of the percentage of trucks in the total volume. Further, variable lane was found to be another important factor that affects the traffic speed. The speed on the right lane is significantly lower than the speed of the left lane at all occupancy levels. The pairwise comparisons reveal that the speed under trucks only condition is significantly higher than at cars only and mixed conditions, and the truck speed at mixed condition is the lowest among the three groups. Moreover, it was found that cars traveled near the speed limit, while trucks were inclined to travel above the speed limits, especially when there were only trucks observed.

Opinion Survey

Introduction

Two surveys were conducted to obtain the opinions of truck drivers on the current lane and speed policies over the Atchafalaya Swamp Freeway. The sample group that was surveyed consisted of truck drivers who are employees of the trucking companies located in the United States and who have driven over the Atchafalaya Swamp Freeway since the lane restriction and 55/60 mph differential speed limit practice began in 2003.

In order to find this specific group, two approaches were taken. The first mail-in survey was conducted using a sample group selected from a list of trucking companies obtained from the weigh station at Butte La Rose. The list contains the trucking companies that violated the weight limit since 2003. The second survey was later conducted online using the LADOTD web site. The results of both surveys are reported in this section.

Mail-In Survey I

The first survey was conducted via mail that was sent out to a list of trucking companies. This list consisted initially of 500 company names, addresses, and phone numbers. However, some entries were duplicates of each other, and after reviewing the data, the number of companies on the list was reduced to 485. Five copies of the survey questionnaire were mailed together with a cover letter and a business reply envelope to each trucking company on the list, requesting that the questionnaires be distributed to eligible drivers within the company to respond to it. In a few months, a total of 159 responses were received back. A sample of the survey cover letter sent out to the trucking companies is provided in Appendix B.

The objectives of the questionnaire were to: (1) gain an idea about the experience of the drivers and how often they travel over this freeway and what type of truck they operate, (2) measure the truck drivers' awareness with the policies in force, (3) find out what drivers think about the safety impact of these policies, (4) measure the effectiveness of warning signs and enforcement on the freeway, (5) find out what urges the drivers to change lanes, and (6) hear the strategies that drivers would propose that might help improve safety and operations on the freeway.

The original survey questionnaire is presented in the next section. The results were illustrated by pie charts and histograms for each question. A sample of the survey results is presented in Appendix C. Conditional percentages were calculated and illustrated by pie charts. Dependence between responses to different questions and reasoning behind responses to certain questions were investigated using chi-square test of independence and canonical correlation analysis at a 95 percent confidence limit. Also, margin of error and confidence intervals were calculated for each test. Interpretations are presented along with the findings.

Survey Questions

ATCHAFALAYA SWAMP FREEWAY TRUCK DRIVER QUESTIONNAIRE

PART 1: GENERAL INFORMATION

1. How many years did you work as a truck driver?

☐ | Less than 1 | ☐ | 1 to 5 | ☐ | 6 to 10 | ☐ | 11 to 15 | ☐ | 16 to 20 | ☐ | More than 20

2. What is the type of vehicle you are currently operating?

☐ | Tractor Semitrailer | ☐ | Straight Truck | ☐ | Other: ____________________

PART 2: ATCHAFALAYA SWAMP FREEWAY

3. Since September 2003, how many times have you traveled on the Atchafalaya section of Interstate 10?

Note: This elevated roadway is located between Lafayette and Baton Rouge. Going eastbound, it starts near Henderson, and ends near Ramah. Please see the map attached.

____

PART 3: POLICY

4. Are you aware of the different speed limits for trucks and cars (55 mph for trucks and 60 mph for cars) at this location?

☐ | Yes | ☐ | No

5. Are you aware of the policy that is restricting trucks to the right lane at this location?

☐ | Yes | ☐ | No

PART 4: SAFETY

6. Do you think the current speed limits might improve the safety at this location?

☐ | Yes | ☐ | No | ☐ | Do Not Know

If yes, to what degree? | ☐ | Significantly | ☐ | Average | ☐ | Not Significantly

7. Do you think the current policy that is restricting trucks to the right lane might improve the safety?

☐ | Yes | ☐ | No | ☐ | Do Not Know

If yes, to what degree? | ☐ | Significantly | ☐ | Average | ☐ | Not Significantly

PART 5: WARNING AND ENFORCEMENT

8. Do you believe that there is sufficient warning about the speed limits and the lane restriction at this location?

☐ | Yes | ☐ | No

9. Do you believe that the legibility of the warning signs is adequate?

☐ | Yes | ☐ | No

10. Have you ever received citation for violation of the speed limit at this location since September 2003

☐ | Yes | ☐ | No | If yes, how many times? ____________________________

11. Have you ever received citation for violation of the lane restriction at this location since September 2003?

☐ | Yes | ☐ | No | If yes, how many times? ____________________________

PART 6: LANE CHANGING

12. What are the two primary reasons you might need to change lanes when driving this road segment?

____

PART 7: FUTURE STRATEGIES

13. Which of the actions below do you think should be taken by the Louisiana Department of Transportation and Development? (you can choose more than one)

Strategies Relating to Speed

- ☐ 1. Keep the 55 mph speed limit for trucks in force
- ☐ 2. Keep the 60 mph speed limit for cars in force
- ☐ 3. Keep the lane restriction in force
- ☐ 4. Change the speed limit for trucks to ________________ mph
- ☐ 5. Change the speed limit for cars to _________________ mph
- ☐ 6. Set different speed limits for left and right lanes: _____ mph for left lane, _____ mph for right lane
- ☐ 7. Reduce the speed limit for all vehicles during the peak hours
- ☐ 8. Place a mechanism on the section that detects an incident and warns the drivers before they approach the scene
- ☐ 9. Place a mechanism that informs a driver of his/her cruising speed versus the posted speed limit
- ☐ 10. Double the fines for speed and lane violations

Lane Restriction Strategies

- ☐ 11. Restrict trucks to the left lane and allow them to change lanes at exits
- ☐ 12. Restrict cars to the left lane and allow them to change lanes at exits
- ☐ 13. Restrict cars to the right lane
- ☐ 14. Restrict a truck to the lane that it was in at the beginning of the section
- ☐ 15. Restrict a car to the lane that it was in at the beginning of the section
- ☐ 16. Do not implement any kind of restriction for trucks
- ☐ 17. Separate left lane from the right lane using barriers

Roadway Lighting Strategies

- ☐ 18. Improve the lighting along the section

Enforcement Strategies

- ☐ 19. Increase the number of law enforcement patrols

Other Strategies (Please Specify)

- ☐ ____
  ____

14. How would this strategy benefit to the traffic safety and operations on this segment, the trucking industry, and the roadway pavement?

____

____

PART 8: ADDITIONAL INFORMATION

15. What else would you like to mention about the lane restriction and speed limit policy for trucks at this location?

____

____

Findings and Interpretations

(Q1) Truck driving experience: As seen in Figure 66, 63 percent of respondents reported more than 10 years of experience, and 32 percent reported more than 20 years. Although 23 percent reported 5 or fewer years, only 1 percent reported driving one year or less.

- *This finding suggests a very experienced pool of respondents.*

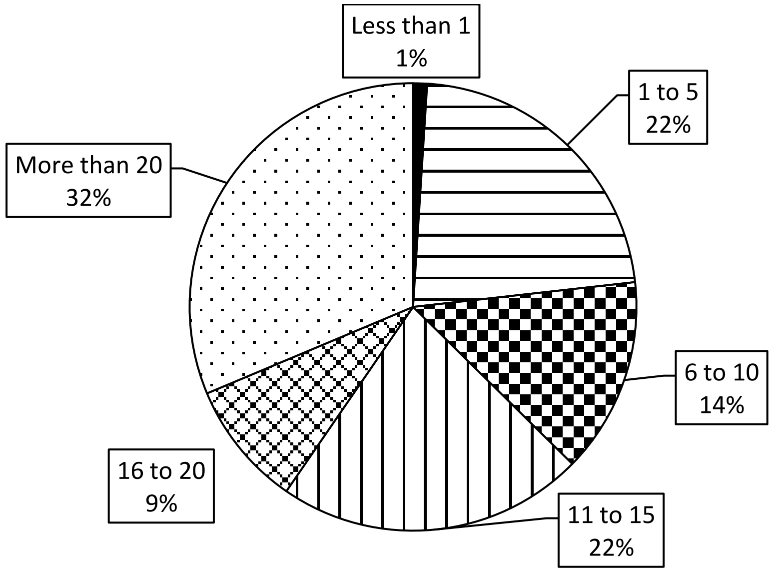


Figure 66
Driver experience

(Q2) Truck configuration: More than 80 percent of respondents reported driving a tractor semi-trailer configuration and 16 percent reported driving a single unit "straight" truck. Only 3 percent reported other configurations, as shown in Figure 67.

- *These findings suggest that tractor semi-trailer configuration is the most common type of vehicle in the survey.*

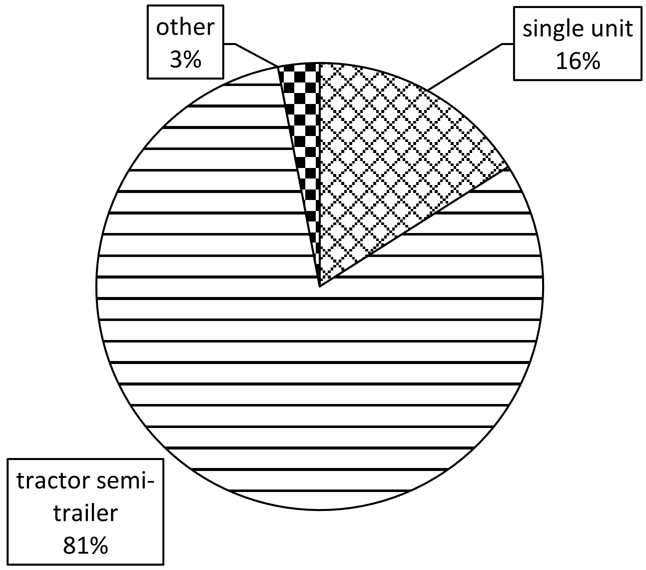


Figure 67
Type of truck operated

(Q3) Frequency of passage over study section is shown in Figure 68. Although a wide distribution of passage rates was observed, it can be seen that the majority of the drivers have driven through the test section 100 or more times since the policy implementation. Specifically 54 percent of respondents reported driving more than 100 times, with 22 percent driving the segment more than 200 times. Only 24 percent reported driving through the segment 25 or less times since the policy change.

- *This finding suggests that the majority of drivers in the survey had driven through the segment on average every 10 days or more often.*

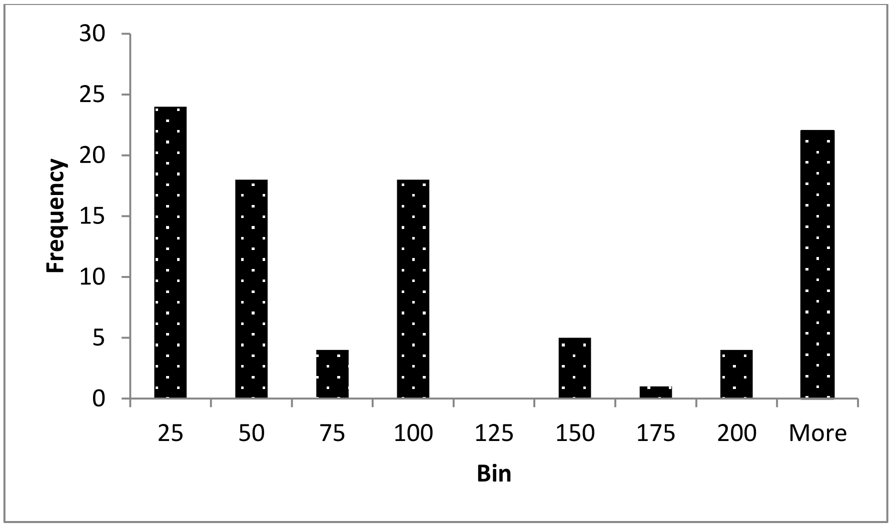


Figure 68
Histogram for the frequency of travel over the section

(Q4) Awareness of differential speed limits: As shown in the chart in Figure 69, most of the respondents, 96 percent, reported being aware of the differential speed limits for cars and trucks.

- *This finding clearly suggests that the information is being effectively communicated and understood.*

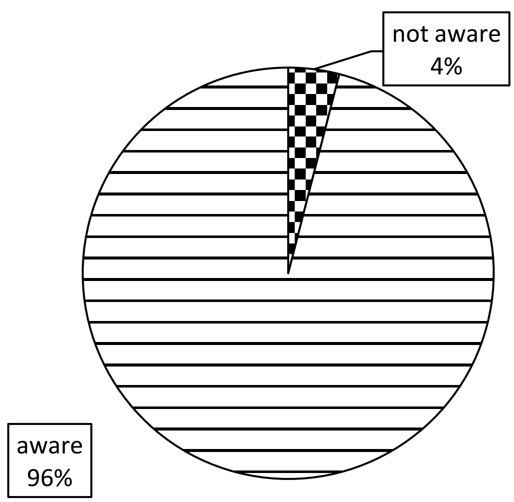


Figure 69
55/60 mph speed limit awareness

(Q5) Awareness of truck lane restriction: 95 percent of respondents reported being aware of the truck lane restriction, as Figure 70 suggests.

- *This finding clearly suggests that the truck lane restriction information is being effectively communicated and understood.*

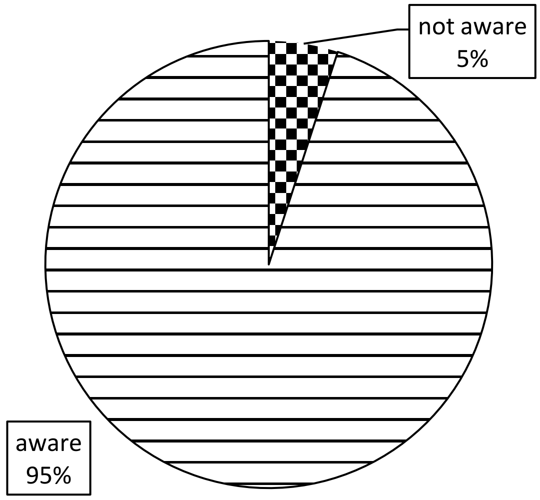


Figure 70
Truck lane restriction awareness

(Q6) Safety impact of speed limits: 32 percent of respondents thought that the speed limits improved safety on the segment, 68 percent thought it had no effect or didn't know (Figure 71). (Q6a) Of those who thought it did have a positive impact, 34 percent felt the benefit was very high while 60 percent thought the benefit was average (Figure 72).

- *These findings clearly suggest that the majority of truckers feel the safety benefits of the speed limit are not significant.*

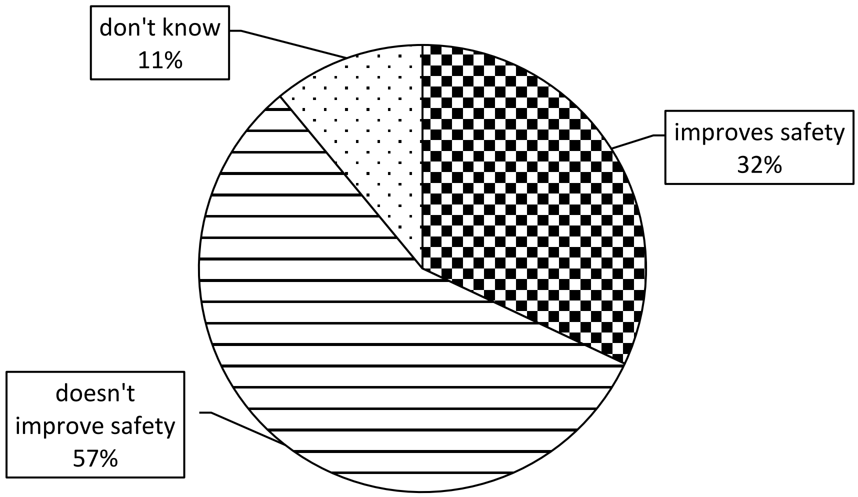


Figure 71
Impact of 55/60 mph speed limit on traffic safety

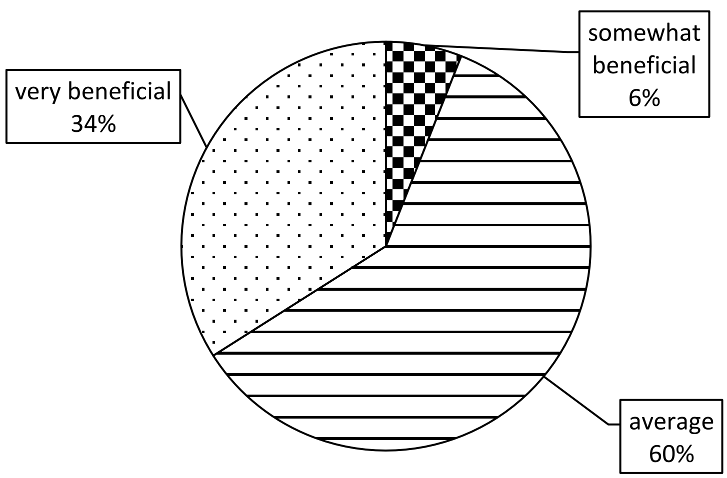


Figure 72
Degree of Impact on Safety

(Q7) Safety impact of lane restriction: Figure 73 shows that the perceived safety benefits of the lane restriction among truckers closely mirrored that of the speed limit in that 34 percent of respondents thought that the lane restrictions improved safety on the segment; 66 percent thought it had no effect or didn't know. (Q7a) Similarly, of those who thought it did have a positive impact, 31 percent felt the benefit was high. While 56 percent thought the benefit was average (Figure 74).

- *These findings correlate with those of the previous question, and suggest that the majority of truckers feel the safety benefits of the truck lane restriction are not significant. It seems that the truck drivers see as intuitive that differential speed limit and truck lane restriction have to be implemented together (78% of those that believe differential speed limit is beneficial safety-wise, also believe truck lane restriction improves safety). However, nearly 25 percent of the interviewees believe that both measures lead to significant safety benefits.*

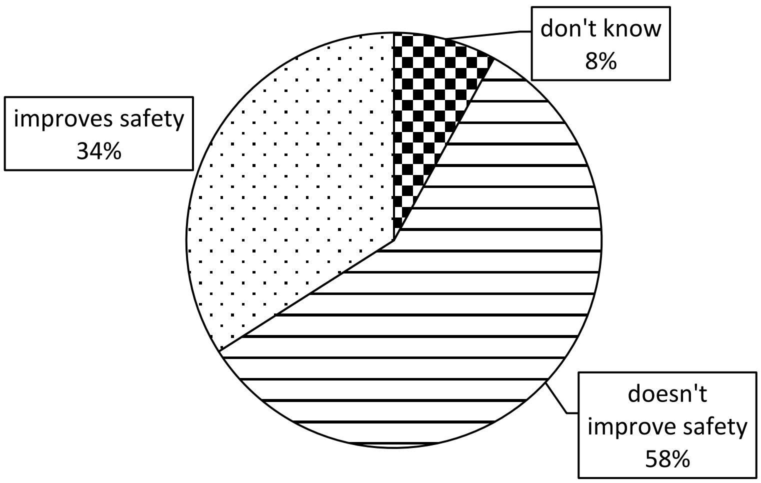


Figure 73
Impact of lane restriction on traffic safety

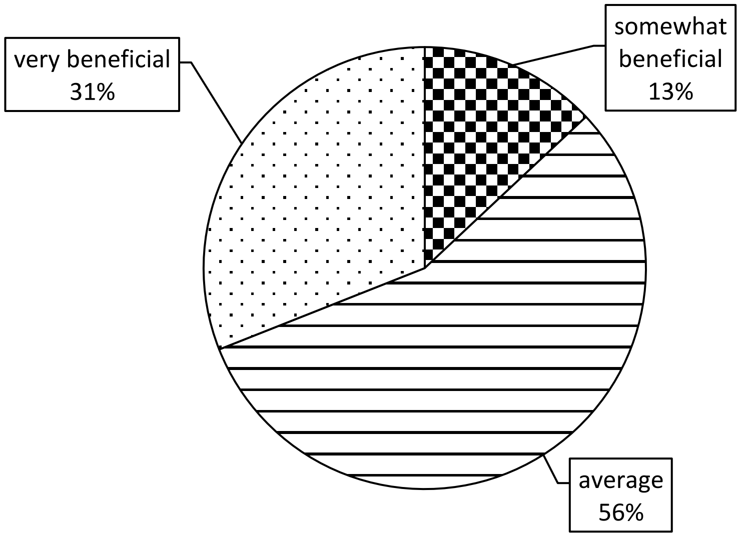


Figure 74
Degree of impact on safety

(Q8) Advanced warning sufficiency: 83 percent of respondents reported that the advanced warning of speed and truck lane restriction was adequate (Figure 75). (Q9) Similarly, 85 percent felt that the warning signs were adequately legible, as shown in Figure 76.

- *These findings clearly suggest that pre-signalization information is being effectively communicated and understood by truckers.*

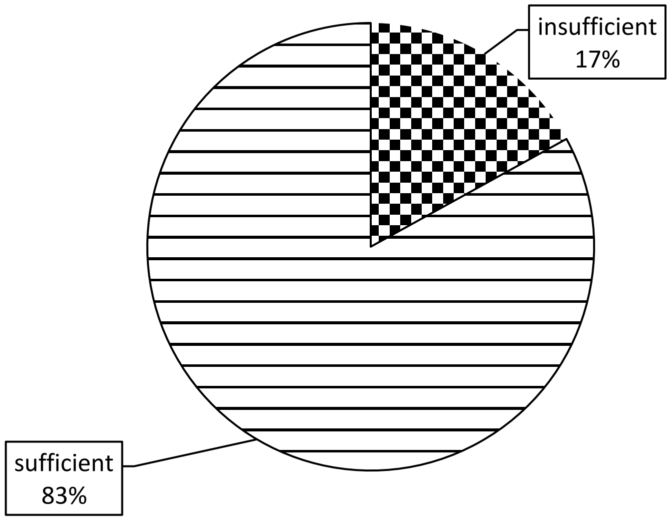


Figure 75
Sufficiency of warning about speed limit and lane restriction

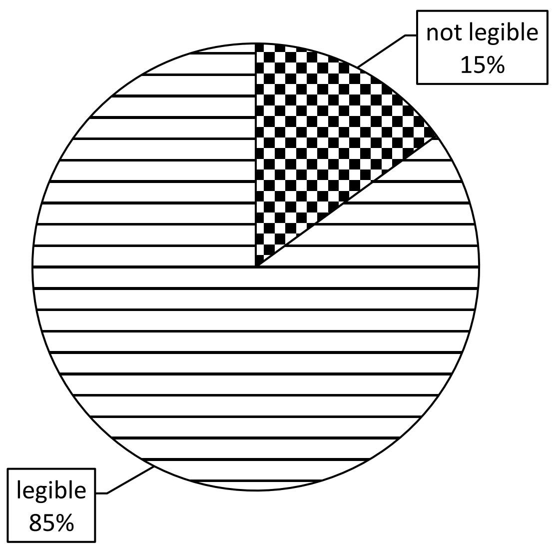


Figure 76
Legibility of roadway signs

(Q10) Violations: The pie chart in Figure 77 illustrates the percentage of respondents who received a speeding ticket. Only 1 percent (2 of the 159 survey respondents) reported receiving a speeding citation since the policy change in September 2003. (Q10a) Of these, both reported receiving two citations. (Q11) Similarly, only 1 percent (2 of the 159 survey respondents) reported receiving a lane change citation since the policy change in September 2003 (Figure 78). (Q11a) Of these, both reported receiving two citations.

- *These findings clearly suggest that only a very small portion of truckers have ever received a citation.*

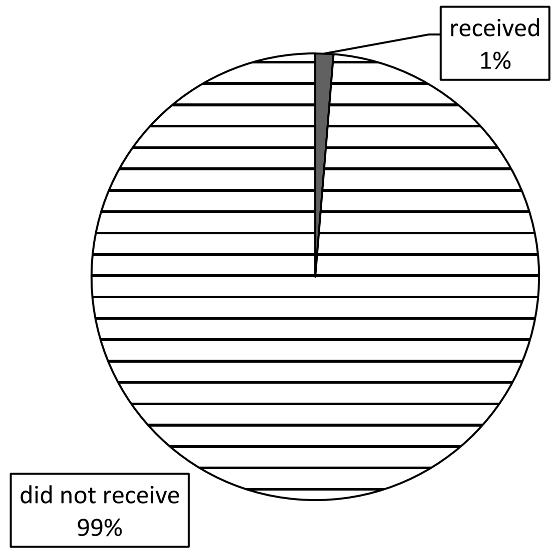


Figure 77
Speeding citation

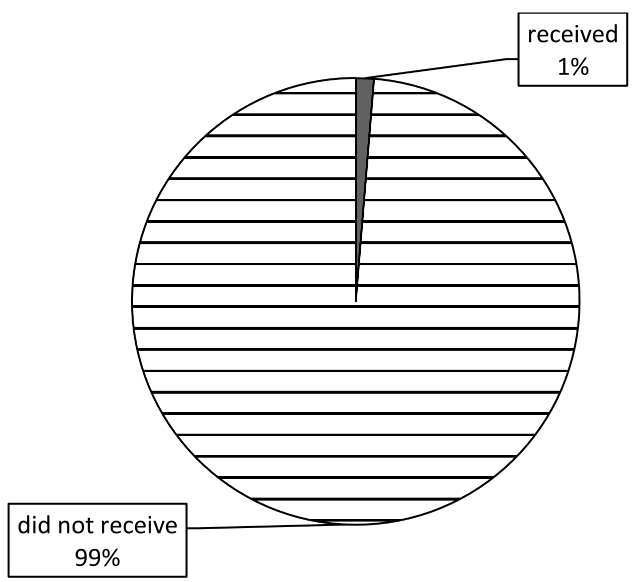


Figure 78
Lane changing citation

(Q12) Reason for Changing Lanes: According to the pie chart in Figure 79, the two most common reasons for making lane changing maneuvers are to pass slow vehicles; for broken down, emergency vehicles, or police vehicles on the shoulder; and to pass vehicles that travel below the speed limit in the right lane. The percentages of the total respondents that stated these reasons are 45 percent and 35 percent, respectively. These reasons are ranked at the top by drivers of all experience levels.

- *This suggests that drivers feel the need to change lanes for safety reasons, and that lane changing behavior is not strongly correlated with driving experience.*

(Q13a&b) Speed Limits: 15 percent of the respondents favored maintaining the current 55 mph truck and 60 mph car speed limits. The remaining 85 percent did not favor its continuation, as shown in Figure 80. (Q13d) Somewhat consistently, 67 percent of truckers favored changing the truck speed limit (Figure 81). (Q13e) 45 percent of the respondents favored changing the speed limit for cars (Figure 82).

- *These findings suggest that, not surprisingly, the respondents are not happy with the current truck speed limit.*

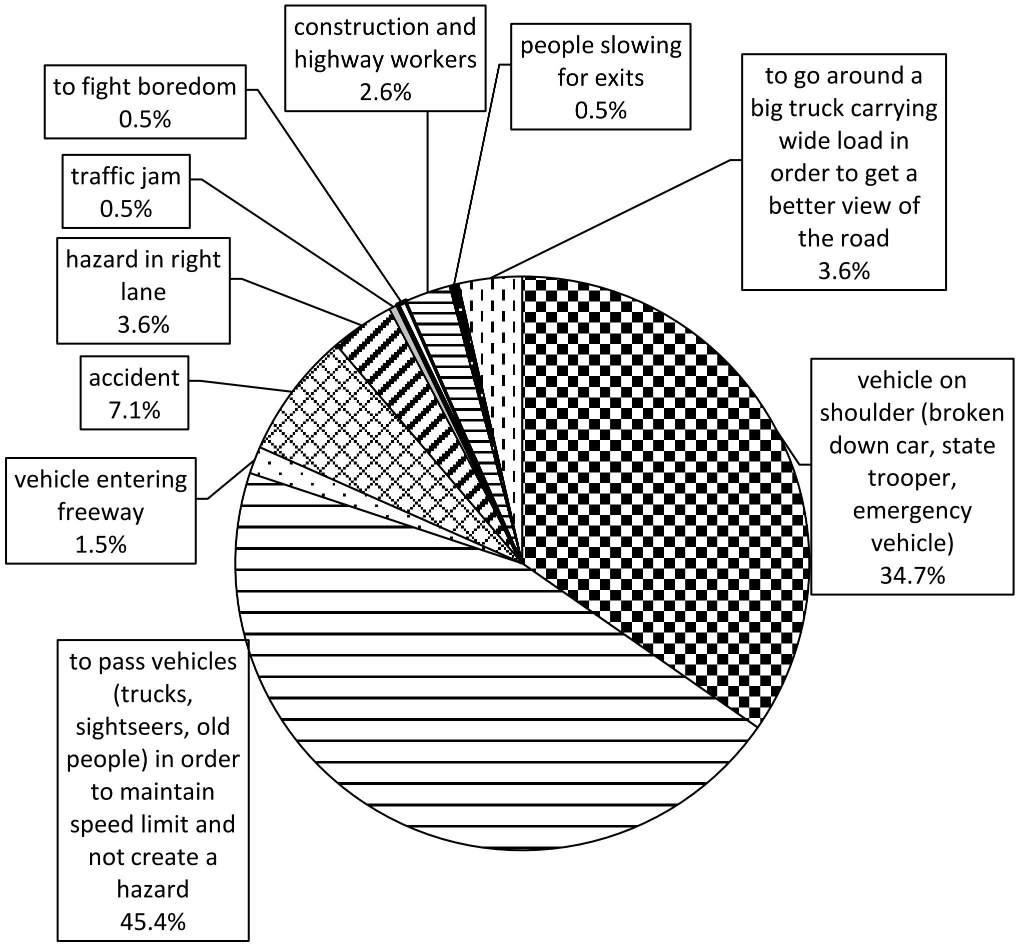


Figure 79
Drivers' reasons for lane changing

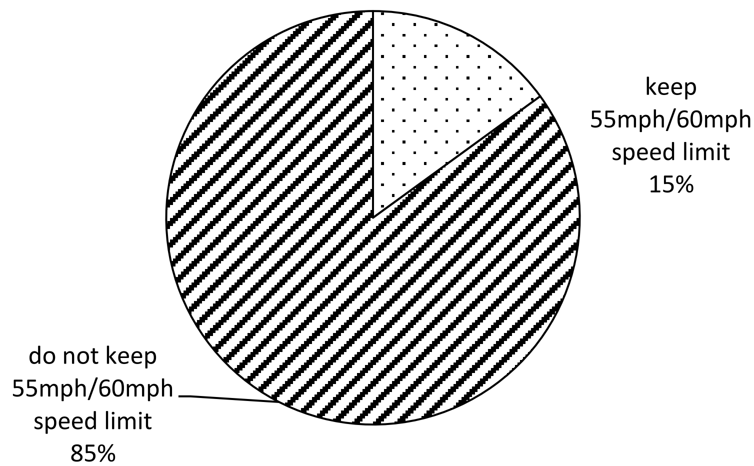


Figure 80
Differential speed limit

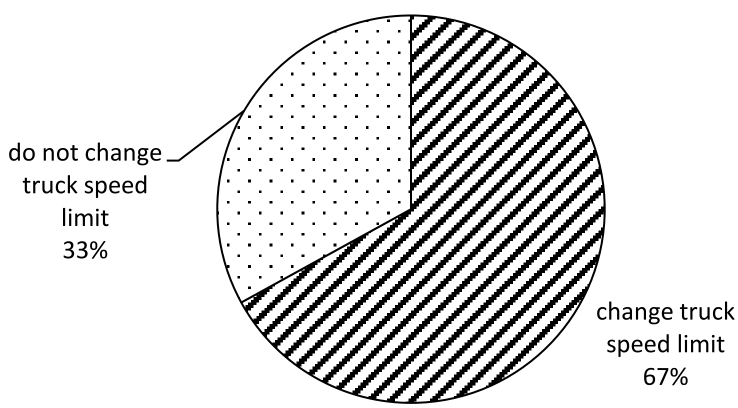


Figure 81
Truck speed limit

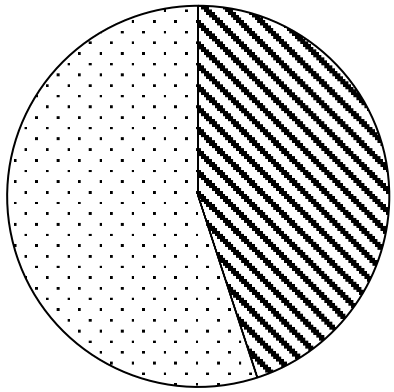


Figure 82
Car speed limit

(Q13f) *Lane-specific s*peed limits: As illustrated in Figure 83, 87 percent of the respondents do not favor differential speed limit for the right and left lanes. Of those who did, 27 percent favored a 70 mph speed limit for the left lane, 32 percent favored 65 mph, 36 percent favored 60 mph, and one respondent favored a decrease to 40 mph. Further, of these respondents, 32 percent favored a 65 mph speed limit for the right lane, 50 percent favored 60 mph, and 18 percent favored 55 mph.

- *These findings suggest that the respondents favor consistent speed limits. Although, for those favoring right and left lane speed limits, the preferred option is 65 mph for the left lane and 60 mph for the right lane on the elevated study segment.*

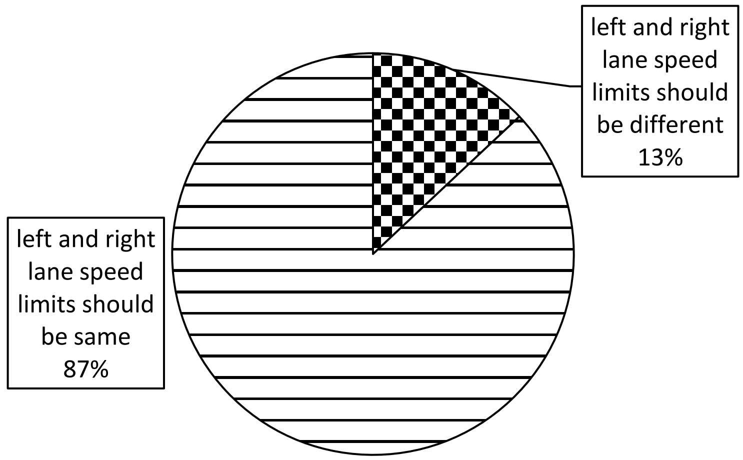


Figure 83
Lane-specific speed limit

(Q13g) Peak-hour speed limits: 89 percent of the respondents did not favor varying speed limits for the peak and no-peak periods. This is depicted in Figure 84.

- *These findings show consistency with earlier results in which the respondents favored consistent speed limits.*

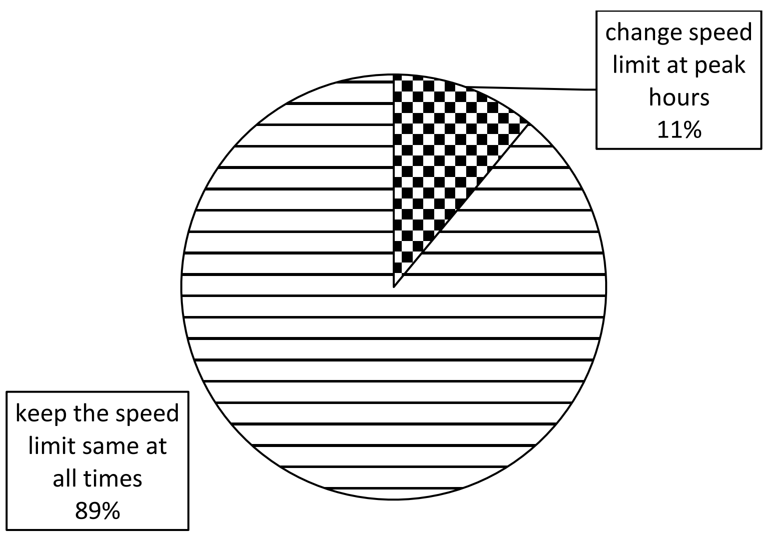


Figure 84
Peak-hour speed limit

(Q13h) Incident detection and warning: 54 percent of the respondents were in favor of incident detection and warning mechanisms (Figure 85) in order to ameliorate safety. (Q13i) However, 75 percent of the respondents did not favor a speed detection that informed drivers of their current speed (Figure 86).

- *These findings suggest that truck drivers welcome additional information about traffic conditions such as occurrence of accidents ahead, but they do not consider that speed monitoring systems add to safety.*

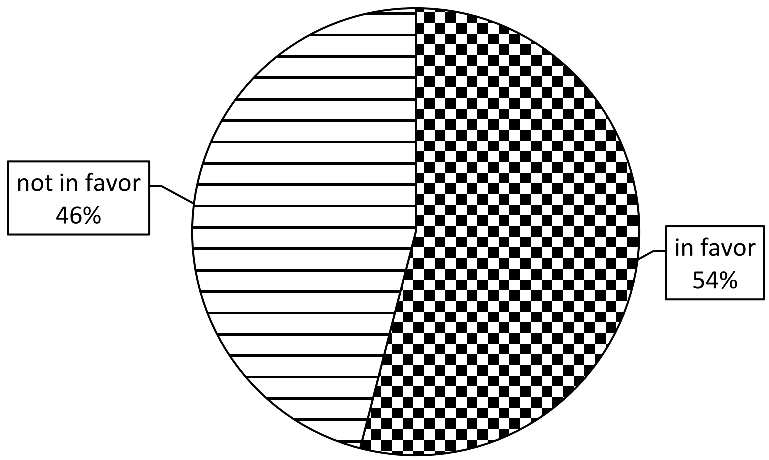


Figure 85
Incident detection system

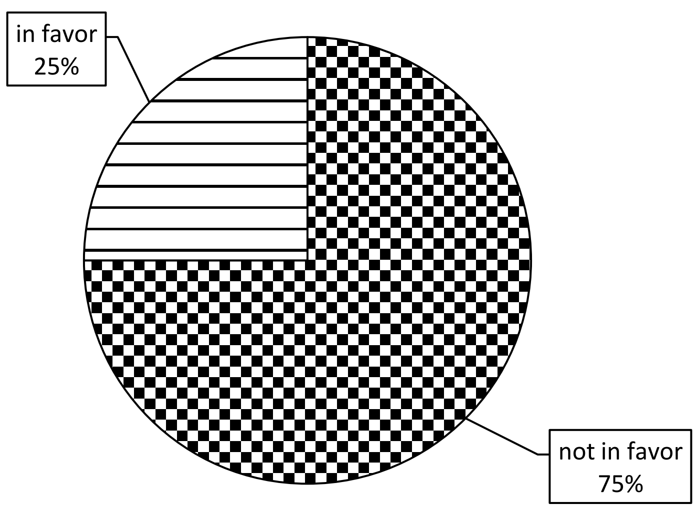


Figure 86
Speed detection and reporting system

(Q13j) Fines: Not surprisingly, 89 percent of the respondents were not in favor of increasing the speed and lane violation fines (Figure 87).

- *This finding suggests that respondents are against raising traffic violation fines.*

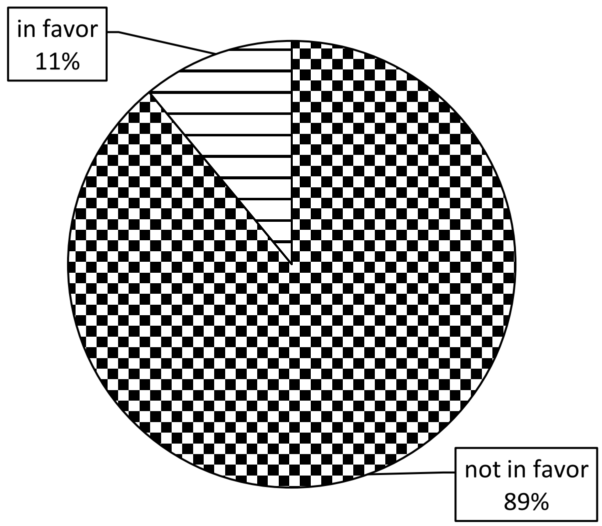


Figure 87
Doubling the violation fines

(Q13c) Similarly only 21 percent of the respondents favored maintaining the current truck lane restriction (Figure 88).

- *This finding shows that the respondents do not favor policies that restrict their movement freedom on the segment.*

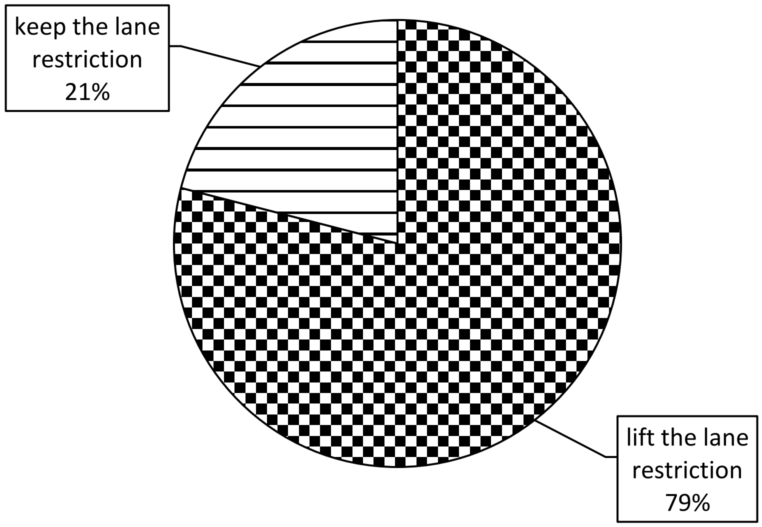


Figure 88
Current truck lane restriction

(Q13 k&l) Left lane restriction: The respondents were quite clear in not preferring left lane restrictions for trucks (89 percent) or cars (92 percent). Figure 89 and Figure 90 present these statistics, respectively.

- *These findings suggest that left lane restriction for any type of vehicle is not a beneficial strategy in the views of the respondents.*

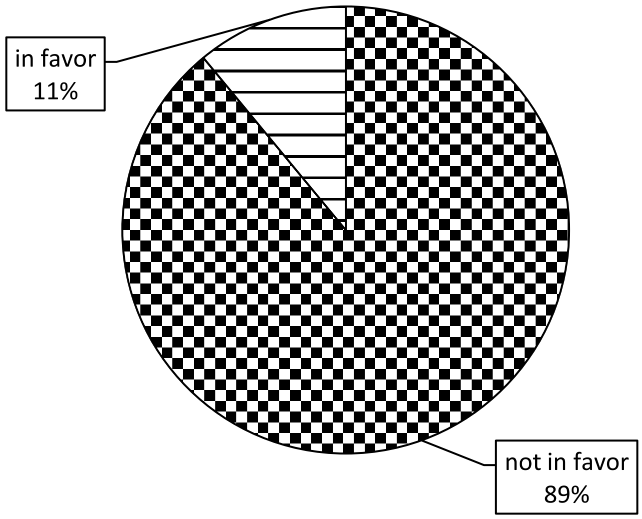


Figure 89
Left lane restriction for trucks

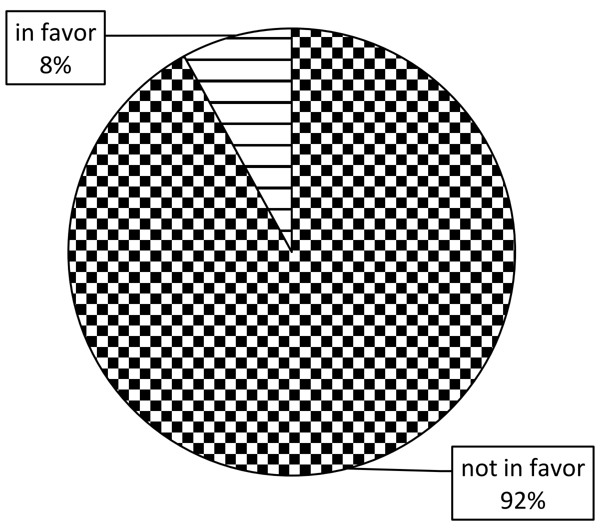


Figure 90
Left lane restriction for cars

(Q13m) Right lane restriction for cars: The respondents were also quite clear in not preferring any right lane restriction for cars (96 percent) along the segment (Figure 91). (Q13 n&o) The respondents were quite clear in not restricting lane position to the location in which the vehicle entered the segment. Figure 92 and Figure 93, respectively, show that this was overwhelmingly true for trucks (94 percent) and nearly unanimous for cars (97 percent).

- *This is consistent with earlier questions in which lane restrictions of any kind was overwhelmingly looked upon unfavorably.*

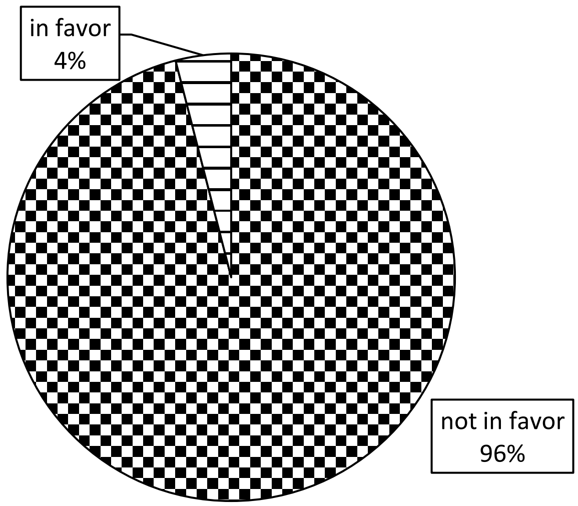


Figure 91
Right lane restriction for cars

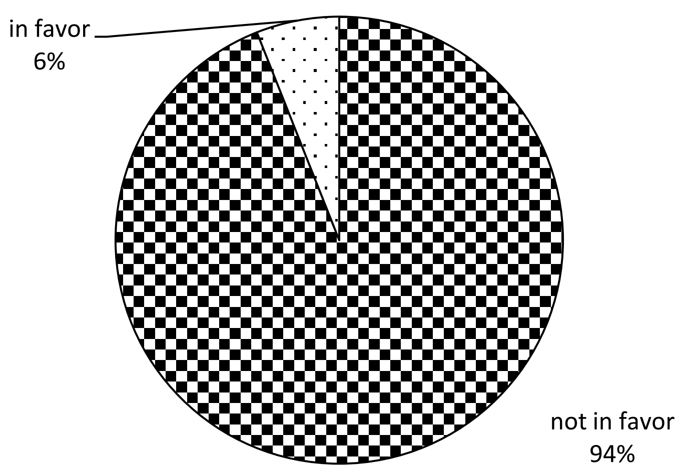


Figure 92
Restricting trucks to the lane in which they enter the segment

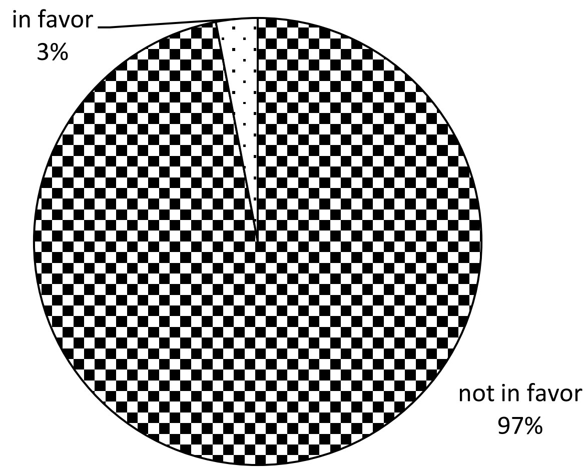


Figure 93
Restricting cars to the lane in which they enter the segment

(Q13p) Do not implement any kind of truck restriction: Interestingly, the consistency for no restrictions on trucks was lessened when respondents were split (58 to 42 percent) on not implementing any restrictions for trucks as depicted by the chart below.

- *This appears to be inconsistent with all earlier questions in which lane restrictions of any kind was overwhelmingly looked upon unfavorably.*

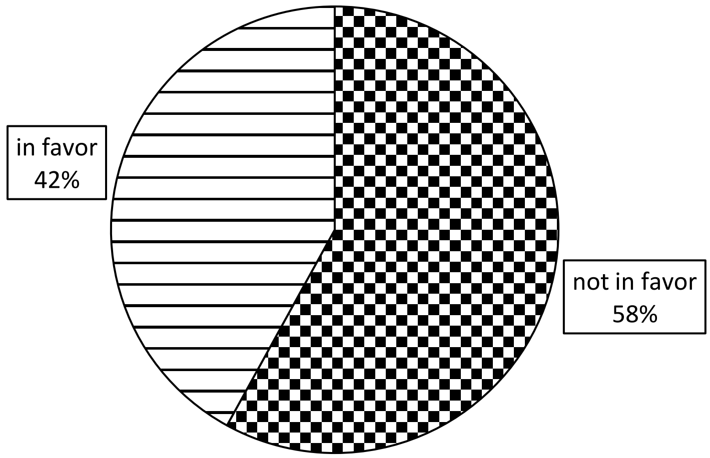


Figure 94
Truck lane restriction in general

(Q13q) Barrier separation: As illustrated by Figure 95, the respondents were clear (96 percent) in not preferring any barriers to separate right and left lane traffic streams.

- *This is consistent with earlier questions in which lane restrictions of any kind was overwhelmingly looked upon unfavorably.*

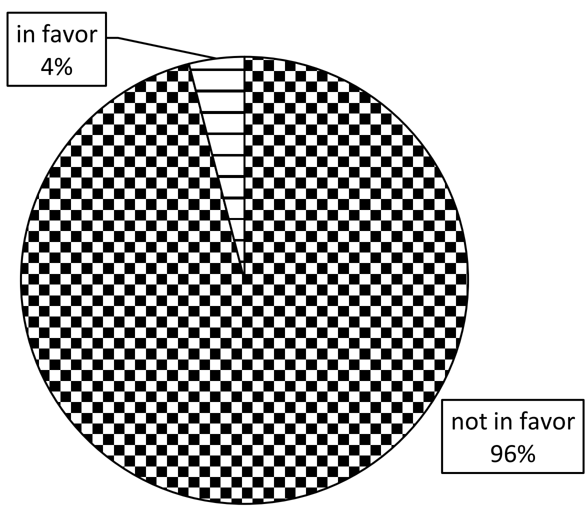


Figure 95
Lane separation by barrier

(Q13r) Lighting improvements: Figure 96 shows that the respondents were split (51-49) on the issue of making lighting improvements on the section.

- *This is one of the strategies that a slightly higher percentage of the respondents were in favor of. This finding suggests a potential need for the lighting improvement over the section.*

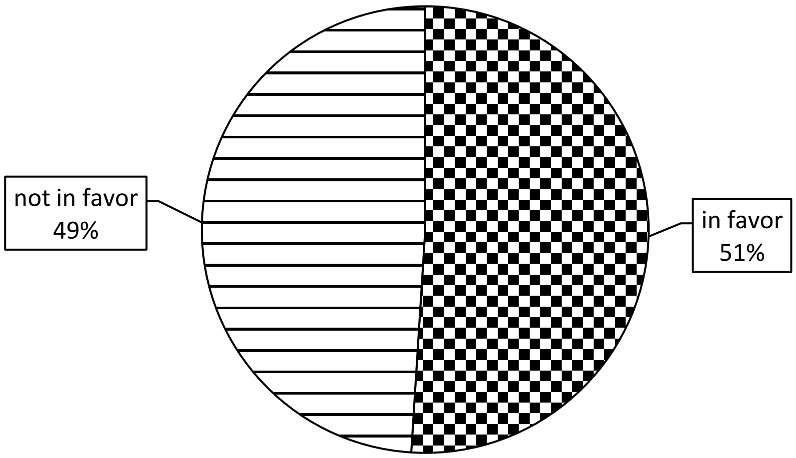


Figure 96
Lighting improvement

(Q13s) Law enforcement improvement: Not surprisingly, majority of the truck drivers (73 percent) are not in favor of enhancing the current law enforcement (Figure 97).

- *These statistics suggest that the current law enforcement is adequate.*

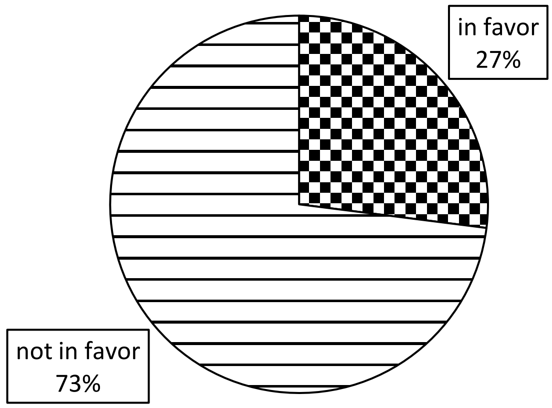


Figure 97
Law enforcement improvement

(Q13t) Other Improvement Strategies: All 24 responses to this question can be grouped in six categories illustrated in Figure 98:

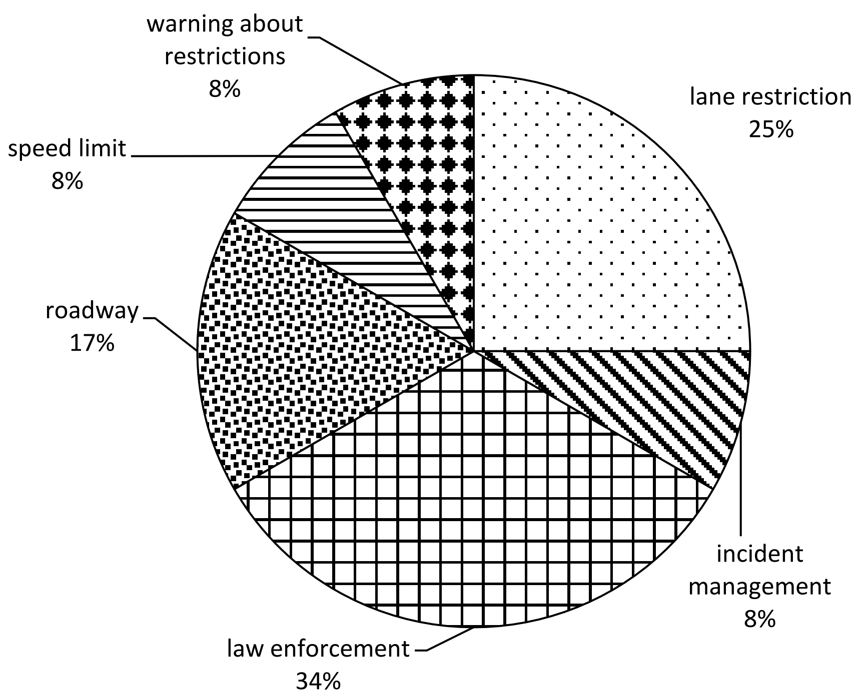


Figure 98
Other improvement strategy areas

The breakdown of each area to the specific suggestions by the respondents is detailed next:

- *Lane restriction related*: 4 respondents suggested letting trucks pass slower trucks and get back over to the right lane; 1 respondent thought dedicating the right lane to commercial vehicles and the left lane to the non-commercial vehicles is a good strategy, and 1 respondent preferred lane restriction only between 10 p.m. and 6 a.m. when there is not much traffic.

- *Speed limit related*: Two respondents suggested a uniform speed limit and one of them stated that the speed limit should be 65 mph.

- *Law enforcement related*: Most of the suggestions were related to this category. Eight drivers responded. One respondent asked for more police coverage during heavy or inclement weather; 1 respondent warned about the gravel trucks' low compliance with the restrictions; 1 respondent suggested employing undercover cops to watch the violators; 1 respondent stated that revoked license and jail time punishments would refrain drivers from speeding; 1 respondent thought that cross-over between two spans is a safe place for police officers to watch the violators; 1 respondent felt that police officers need to ride on a truck during their training to observe the traffic on the segment; and 1 respondent brought up an idea of installing cameras on the bridge.

- *Roadway characteristics related*: 1 respondent suggested widening the shoulders; 1 respondent stated that the section needs to be repaved; 1 respondent pointed out the necessity of placing white stripes in rainy weather; and 1 respondent wrote that cut grooves could help prevent hydro-planning.

- *Accident/emergency related*: 1 respondent suggested opening up the cross-over between two spans for broken down vehicles, and 1 respondent stated that more emergency assistance is necessary.

- *Restriction warning related*: 2 respondents suggested placing more signs that warn about the restrictions.
    - *These findings suggest that there could be alternative ways to achieve amelioration of safety by improving law enforcement, implementing lane restriction, and enhancing roadway physical characteristics.*

(Q14) Benefits of proposed improvement strategies: Respondents reported that an incident reporting mechanism over the stretch would allow drivers to adjust their speed, switch to the secure lane, and have a cautious attitude ahead of time before they approach the incident scene so that bigger hazards can be prevented.

Improved lighting would lead to better night-time visibility, making the ride safer for the driver and help identify stopped vehicles on the shoulder.

Figure 99 shows that 57 percent of the responses about the benefits of a speed limit change were operations related, whereas 43 percent were safety related.

- *The earlier suggestion about drivers' preference of operational benefits over the safety benefits still holds true.*

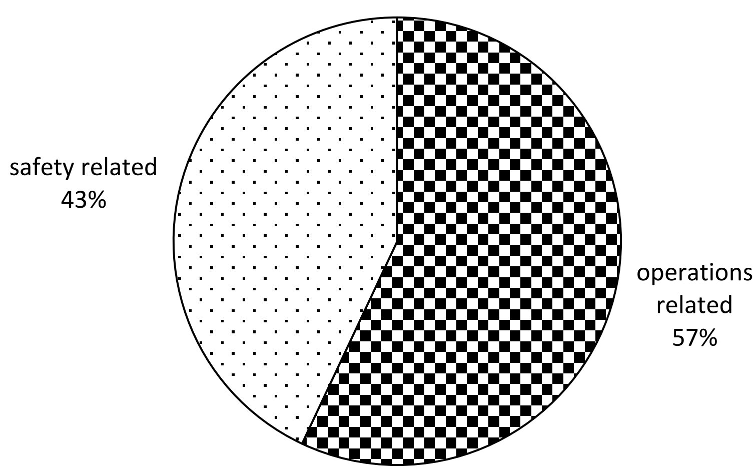


Figure 99
Benefits of proposed speed limits

The safety benefit of a new speed limit is stated to be the reduction in conflict between vehicles. As illustrated in Figure 100, about three quarters of the respondents reported that the new speed limit will lessen the need to change lanes, while one quarter claimed that it will help prevent rear-end collisions.

- *This finding suggests that respondents see the lane changing as the main cause of traffic accidents on this segment.*

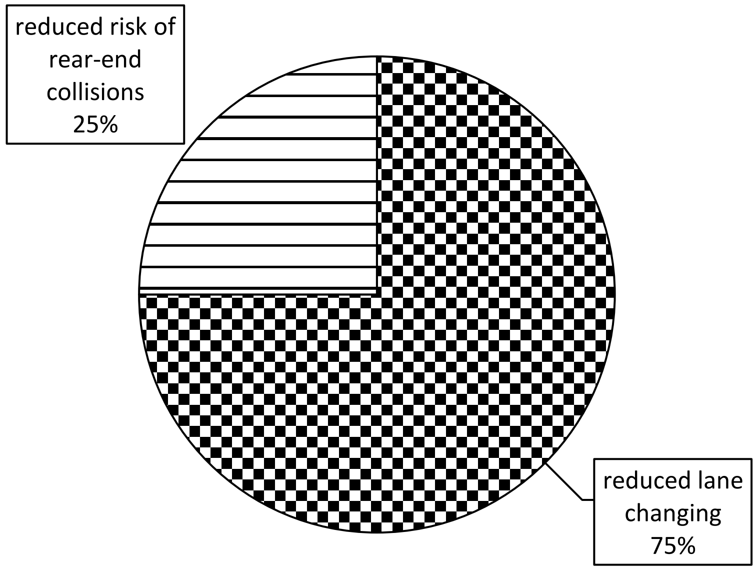


Figure 100
Safety related benefits of speed limit change

Of the respondents who considered operational benefits, 38 percent reported that the new speed limit will bring smoother flow, 33 percent claimed it will reduce clustering of trucks and backups, 13 percent suggested it will decrease time loss, 8 percent perceived them as improvements in driving comfort related to slow driving speeds, 4 percent indicated that slow cruising speeds impact driver's alertness, and 4 percent regarded them as a facilitation of exiting maneuvers. These results are presented in Figure 101.

- *These findings suggest that majority of the respondents want a better flow and less backups and clustering of trucks in the right lane.*

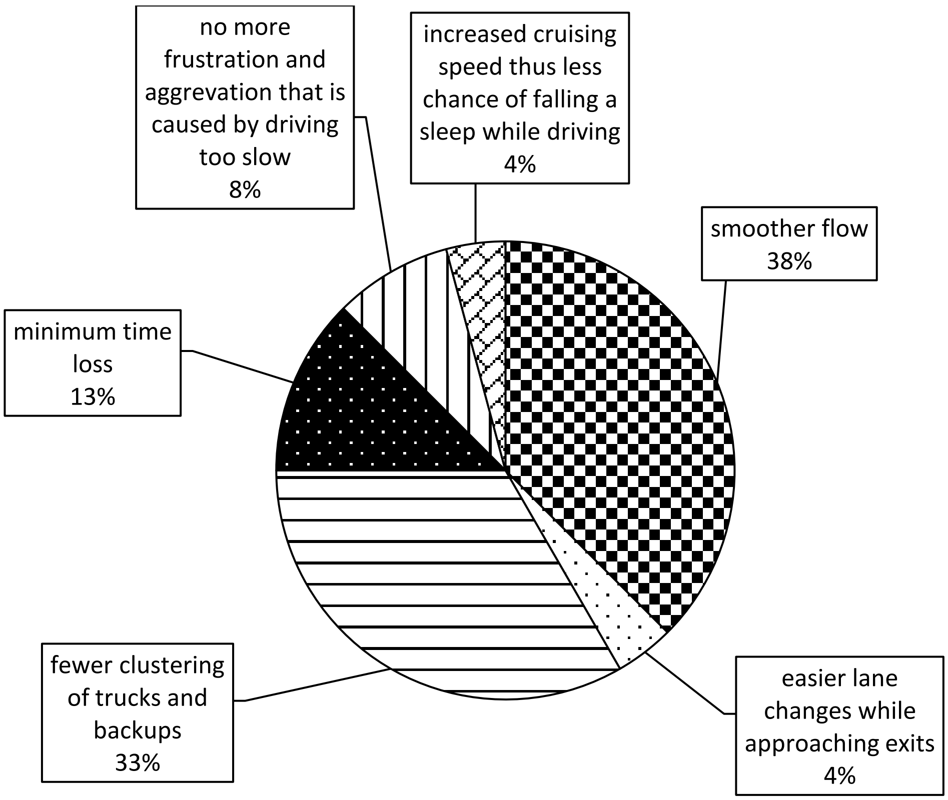


Figure 101
Operation related benefits of speed limit change

The speed limit suggestions for the stretch are illustrated in Figure 102. The question marks indicate no preference. The figure shows that 17 percent of the respondents believed that the current 55/60 mph differential speed limit should be kept in force. The figure also shows that 15 percent thought the speed limit should be 60 mph for both trucks and cars. The results also show that 13 percent suggested that truck speed limit be 60 mph, but they did not specify any speed limit for cars. Another 13 percent stated that 65 mph should be the speed limit for both trucks and cars. Nearly 7 percent were in favor of a uniform speed limit for cars and trucks, too, but this group's suggested speed limit was 70 mph.

- *Surprisingly, the group with the highest percentage is the one that is in favor of keeping the current 55/60 mph differential speed limit; however, it is assumed that this is because the respondents who were in favor of changing the speed limit but did not propose any measure for it were not included in the total number of respondents who suggested new speed limit. The respondents' choice of 60 mph uniform speed limit or 65 mph uniform speed limit as the top two options is a result that was expected. Truck drivers want to drive as fast as automobile drivers. It can be concluded from Figure 102 that 75 percent of the respondents who suggested new speed limits were in favor of raising the truck speed limit.*

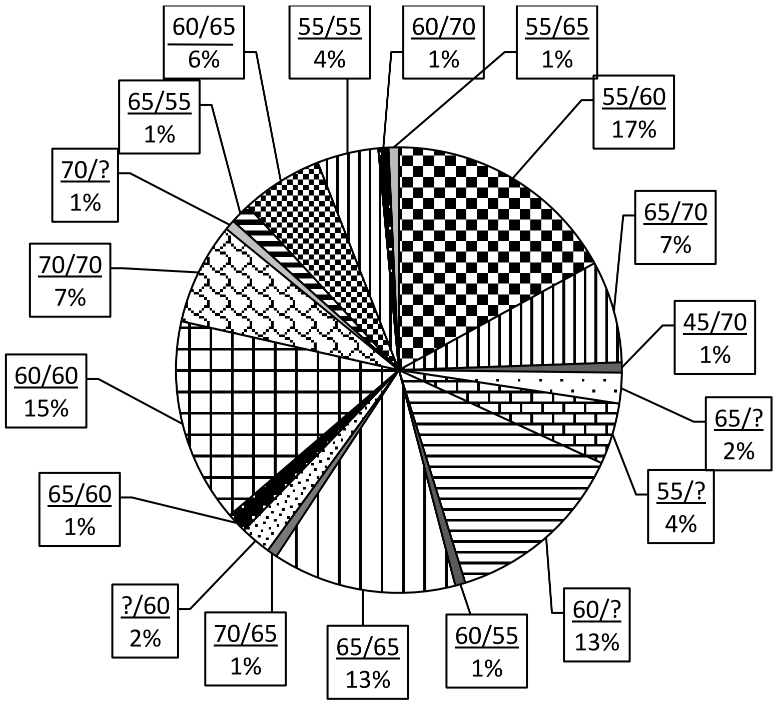


Figure 102
Speed limit suggestions (trucks/cars)

As illustrated in Figure 103, 29 percent of the respondents who stated the benefits of a new speed limit, mentioned above, believe that 60 mph uniform speed limit will be the most beneficial. The second most beneficial speed limit came out to be 70 mph uniform speed limit with response rate 21 percent. The percentage that stated benefits for 60 mph for truck speed limit but did not suggest any car speed limit was 14. The figure shows that 11 percent thought 65 mph uniform speed limit would bring some benefits.

- *These findings suggest that truck drivers believe in the benefits of a uniform speed limit and a truck speed limit higher than the current 55 mph.*

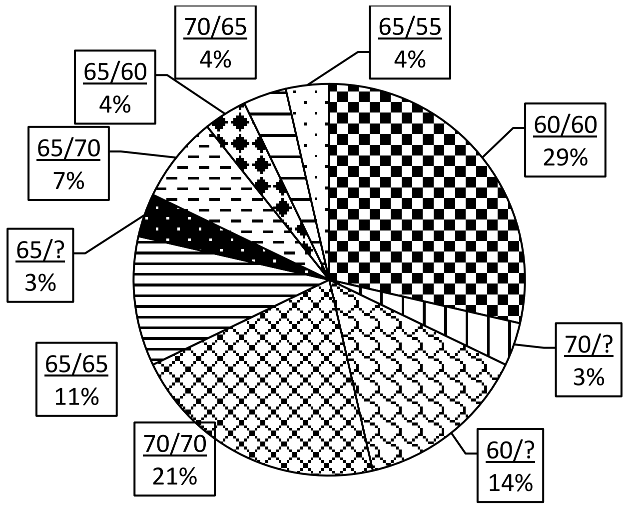


Figure 103
Speed limit suggestions that will bring certain benefits (trucks/cars)

Figure 104 shows the breakdown of the respondents who specified certain speed limits that will improve the flow. The choice of 23 percent was 60 mph uniform speed limit. The figure shows that 22 percent wrote 65 mph for the uniform speed limit, and another 22 percent stated that their preference is 60 mph for truck speed limit but did not provide any answer for the car speed limit.

- *These statistics suggest that, in the views of the respondents, a differential speed limit affects the traffic flow adversely. A 60-mph truck speed limit dominates over 65 mph and 70 mph alternatives.*

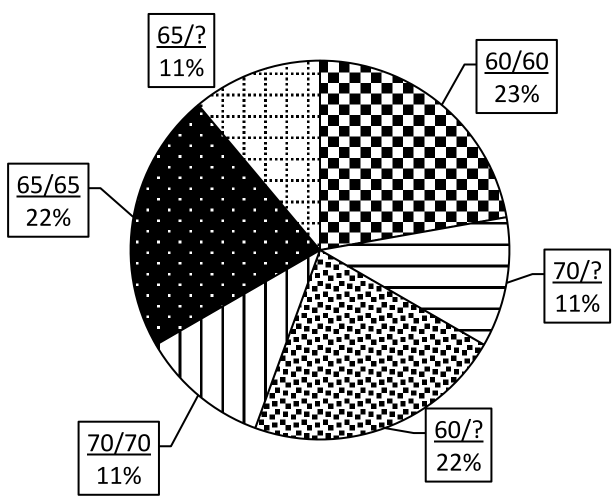


Figure 104
Speed limit suggestions for smoother flow (trucks/cars)

Of the respondents who thought clustering and backup of trucks could be reduced by changing the speed limit, 43 percent suggested 60 mph uniform speed limit; 29 percent suggested 60 mph truck speed limit but did not specify any speed limit for cars; 14 percent suggested 70 mph uniform speed limit, and the remainder 14 percent suggested 65 mph truck speed limit and 70 mph car speed limit. The results are depicted in Figure 105.

- *These findings show a similar trend with the previous ones. The majority of the respondents prefer a 60-mph truck speed limit to reduce clustering and backup of trucks. Even though raising the speed limit 5 mph from 55 to 60 mph is a small change on the scale, truck drivers believe in its operational benefits. On the other hand, a uniform speed limit superseded over a differential speed limit in this question too.*

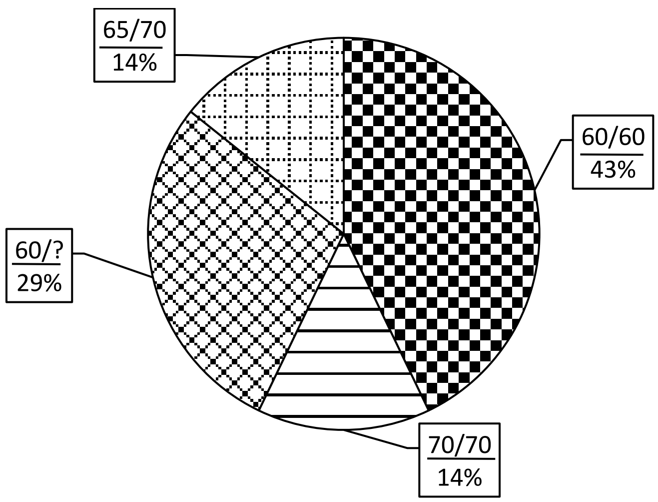


Figure 105

Speed limit suggestions for fewer clustering and backup of trucks (trucks/cars)

Among the respondents who stated that a change in the speed limit would lead to time savings, the group that suggested a 65-mph truck speed limit and a 60-mph car speed limit topped the list with 34 percent as seen in Figure 106. The figure shows that 33 percent suggested a 70-mph uniform speed limit, and the remaining 33 percent suggested a 70-mph truck speed limit and a 65-mph car speed limit.

- *The majority of the respondents, 67 percent, preferring the truck speed limit to be higher than the car speed limit in order to save time is an interesting finding. But it is not surprising to see that the majority of the respondents suggested such a high truck speed limit, 70 mph, to reduce truck travel time.*

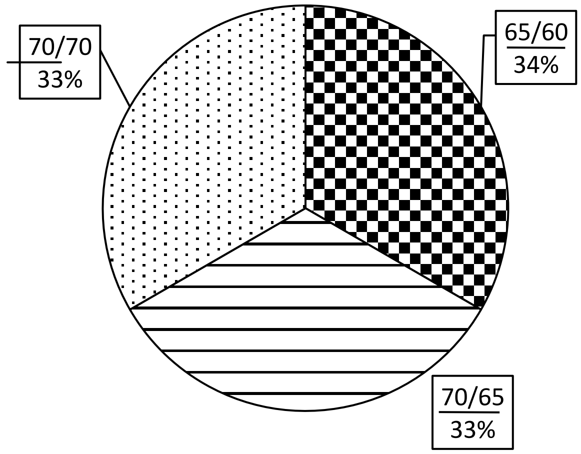


Figure 106

Speed limit suggestions for minimizing time loss (trucks/cars)

Figure 107 presents two sets of speed limits that were thought to reduce aggravation and frustration caused by slow moving traffic. These are 65/70-mph speed limits (trucks/cars) and a 70-mph uniform speed limit. The number of respondents in both groups is equal.

- *This finding suggests that respondents prefer high speed limits such as 65 mph or 70 mph in order to keep them alert while driving.*

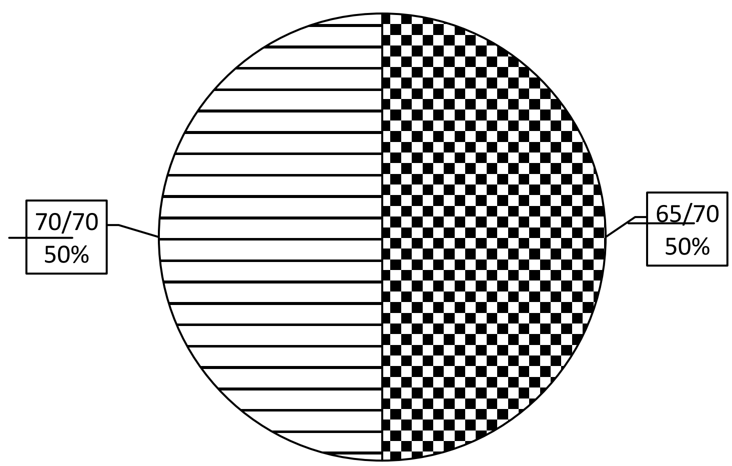


Figure 107

Speed limit suggestions to eliminate frustration and aggravation (trucks/cars)

Half of the respondents who proposed a speed limit change to decrease the frequency of lane changing maneuvers were in favor of a 60-mph uniform speed limit, while 33 percent supported a 70-mph uniform speed limit, and 17 percent suggested an increase in the truck speed limit to 65 mph and a decrease in the car speed limit to 55 mph. Figure 108 illustrates these results.

- *This finding suggests that majority of the respondents are in favor of a uniform speed limit that is higher than 55 mph to reduce the frequency of lane changing maneuvers. Uniform speed limit suggestion is understandable but a 65-mph/55-mph differential speed limit is a surprising response, unless truck drivers assume that cars go much faster than the posted speed limit.*

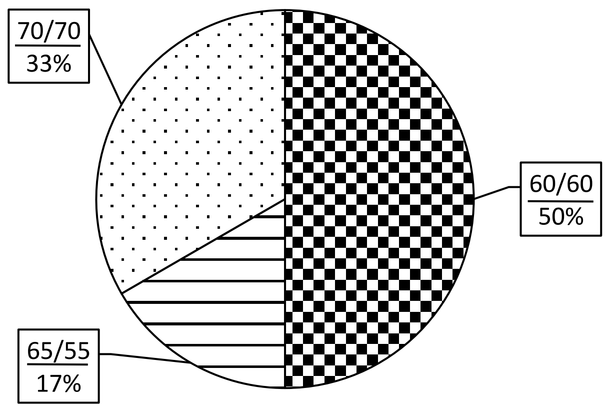


Figure 108
Speed limit suggestions to reduce lane changing (trucks/cars)

There is usually a high chance of conflict between vehicles, therefore, causing higher frequency of lane changing maneuvers when there is differential speed limit. The following findings take this idea as the basis for speed limit suggestion.

According to some respondents, a differential speed limit prepares the scene for rear-end collisions. Figure 109 shows that half of these respondents thought that reduction in this type of collision can be made possible by increasing the speed limit to 70 mph for both trucks and cars. The other half stated that a 65-mph uniform speed limit could be a solution.

- *A 65-mph or 70-mph uniform speed limit suggestions to reduce rear-end collisions might help traffic flow steadily, but one problem with these high speed limits is that the vehicles, especially 18-wheelers and other heavy vehicles, merging from the on-ramps might have difficulty accelerating to these high speeds in a short period of time. This situation might lead to a higher risk for rear-end collisions near the ramps.*

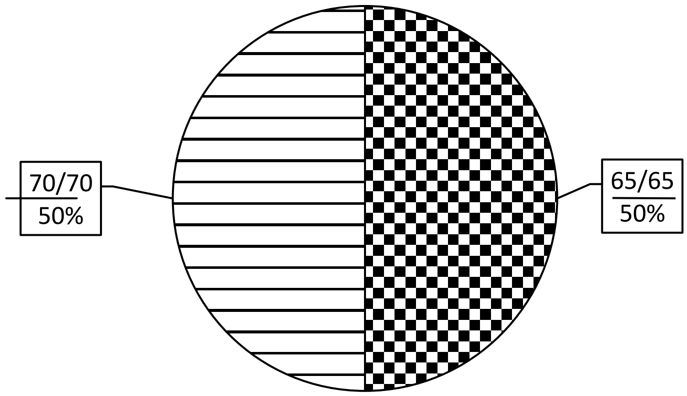


Figure 109
Speed limit suggestions to reduce the risk of rear-end collisions (trucks/cars)

(Q15) Comments: One respondent was happy with the current restrictions, while some of the respondents who were not pleased stated their complaints. One respondent reported that trucks on the right lane obstruct the road view of the drivers approaching from behind. Two respondents pointed out that lane restriction causes backup of trucks and one respondent thought the low speed limit is responsible for the backup. One respondent indicated that lane restriction makes it difficult for oncoming traffic to merge. Three respondents complained about cars weaving in and out. Also, one respondent mentioned that 55 mph speed limit is too low for trucks, and another driver claimed that this speed limit impacts drivers' alertness negatively by making them sleepy.

The majority of the respondents proposed strategies. One respondent suggested increasing the speed limit to 65 mph for both cars and trucks, and lifting the lane restriction only between 10 p.m. – 6 a.m. Fourteen respondents thought uniform speed limit practice could reduce the frequency of rear-end collisions, lane changing maneuvers, and truck backups. Three respondents reported that trucks in the right lane should be able to use the left lane to pass. Only six respondents suggested lifting both restrictions to eliminate backups and lane changing maneuvers. While one respondent stated that more enforcement is needed to prevent violations by truck drivers, three respondents thought that more enforcement should be provided to prevent cars from weaving in and out. Also, two respondents proposed incident management ideas, such as the need for better emergency assistance, and opening the crossovers between the two spans for broken down vehicles. Better warning about the restrictions, reserving the left lane for passing movements only, increasing the speed limit, widening the shoulders, and imposing restrictions on cars besides trucks were the other strategies put forward by five different respondents.

- *These findings suggest that the majority of the respondents believe uniform speed limits would make the road safer and more efficient. Also, it can be inferred from the comments that lifting the lane restriction, too, might help reduce backups and lane changing maneuvers. These findings are consistent with the ones from previous questions in that truck drivers want more freedom of movement and smoother flowing traffic.*

Conditional Percentages

The following inquiries investigate how certain questions on the questionnaire were answered by certain subsets of respondents in order to identify relationships and validity of answers.

1. Is the number of citations received related to the driving experience? What percentage of drivers with experience more than 5 years received citation?

The driving experience is not related to the number of citations received. Illustrated in Figure 110 and Figure 111, respectively, 1 percent of the drivers that have more than 5 years of experience (or 2 out of 159 drivers) claimed that they received speed violation tickets and 0.6 percent (or 1 out of 159 drivers) claimed they received lane violations tickets.

- *It is difficult to measure this relation since there are very few respondents who reported that they received citations. This suggests that either this pool of survey sample obeys the rules or they do not want to disclose their violations.*

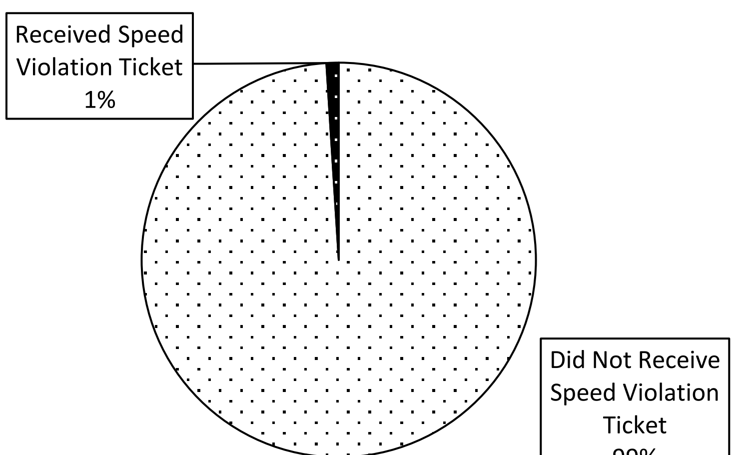


Figure 110
Drivers with 5 or more years of experience that received speed violation tickets

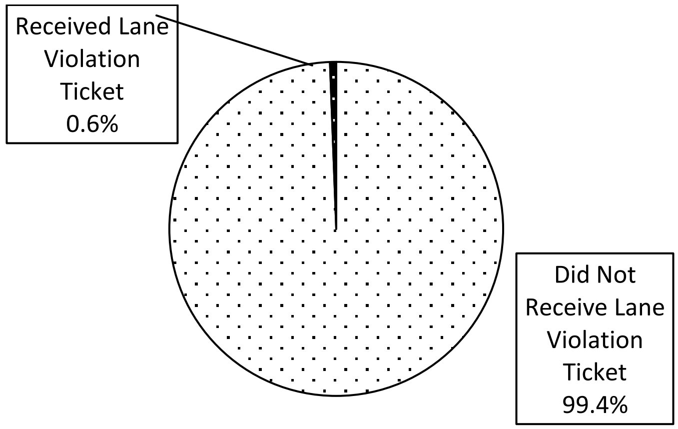


Figure 111
Drivers with 5 or more years of experience that received lane violation tickets

2. For different driving experience levels, what is the percentage of drivers that think the current speed limit improves safety?

The percentage of drivers that think the current speed limit improves safety decreases as the driving experience level increases. Looking at Figure 112, it is seen that this value is 50 percent (or 1 out of 2) for the drivers with less than 1 year driving experience and 53 percent (or 17 out of 32) for drivers with 1 to 5 years of experience. The value reduces to 33 percent (or 7 out of 21) for drivers with 6 to 10 years of experience, and then to 31 percent (or 11 out of 36) for the 11 to 15 years category. About 21 percent (or 3 out of 14) of the respondents that have 16 to 20 years of experience and 23 percent (or 11 out of 48) of the respondents with higher than 20 years of experience think that the current speed limit improves safety.

- *This implies that less experienced drivers (i.e., 5 years or less) are more optimistic about the safety benefits of a differential speed limit than more experienced drivers.*

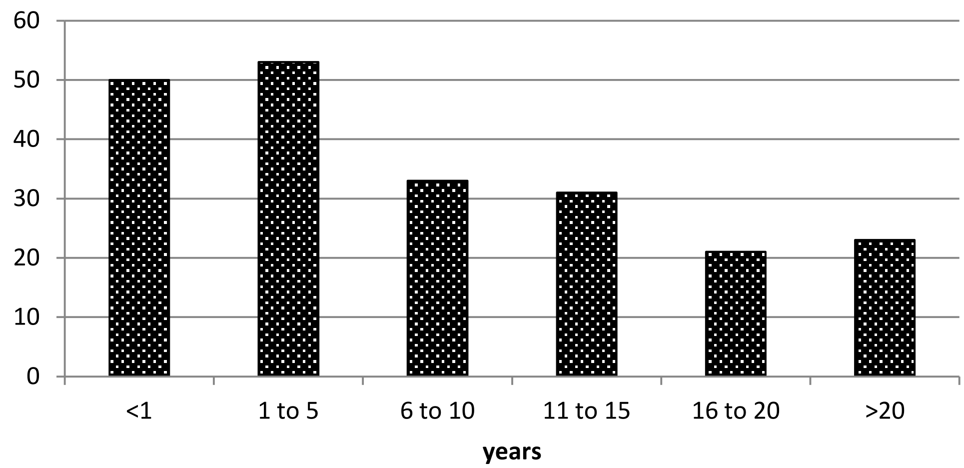


Figure 112
Drivers at different experience levels who think the current speed limit improves safety

3. For different driving experience levels, what is the percentage of drivers that think the current lane restriction improves safety?

As pictured below, the percentage of drivers that think the current lane restriction improves safety doesn't show a consistent trend over the experience levels. This value is 50 percent (or 1 out of 2) for the drivers with less than 1 year driving experience and 50 percent (or 16 out of 32) for drivers with 1 to 5 years of experience. The value reduces to 29 percent (or 6 out of 21) for drivers with 6 to 10 years of experience and then increases to 34 percent (or 12 out of 35) for 11 to 15 years category. About 21 percent (or 3 out of 14) of the respondents that have 16 to 20 years of experience and 29 percent (or 14 out of 48) of the respondents with higher than 20 years of experience think that the current lane restriction improves safety.

- *This trend suggests that respondents that have 5 years or less driving experience are more optimistic about the safety benefits of lane restriction than drivers at higher experience levels.*

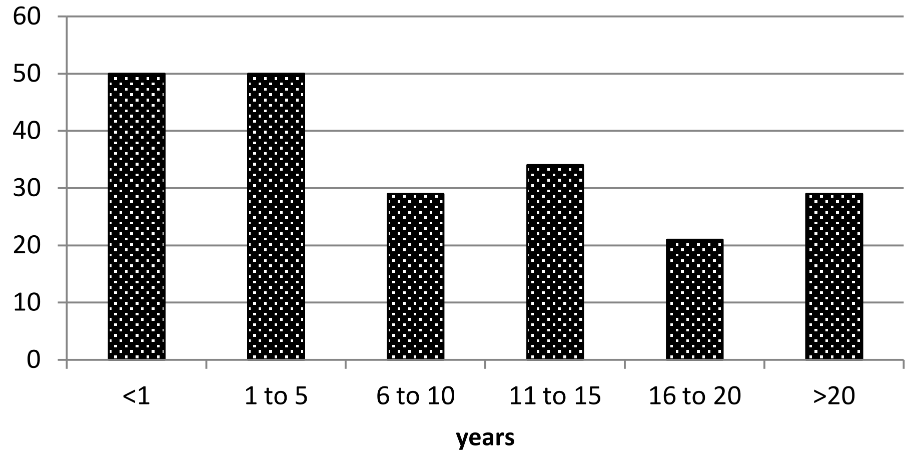


Figure 113
Drivers at different experience levels who think the current lane restriction improves safety

4. For drivers of different truck types, what is the percentage of drivers that think the current speed limit improves safety?

Figure 114 shows that 26 percent of the tractor semitrailer drivers (or 30 out of 117) think that the current speed limit improves safety; whereas, this percentage rises to 56 percent (or 15 out of 27) for smaller truck drivers.

- *This finding suggests that smaller truck drivers believe in the safety benefits of the current speed limit but tractor semi-trailer drivers do not.*

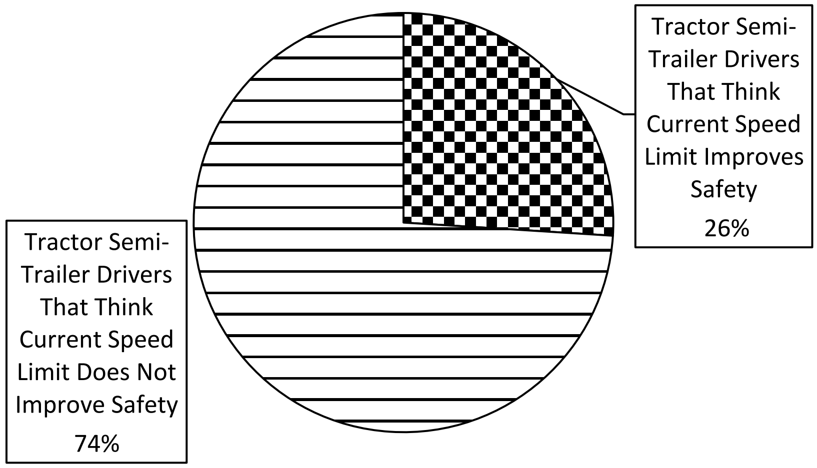


Figure 114
Safety impact of the current speed limit in the views of the tractor semi-trailer drivers

5. For drivers of different truck types, what is the percentage of drivers that think the current lane restriction improves safety?

Safety benefits related to current lane restriction is thought by 27 percent of the tractor semitrailer drivers (Figure 115); whereas, this measure increases to 60 percent (or 15 out of 25) for smaller truck drivers (Figure 116).

- *These findings are consistent with the previous ones. They suggest that smaller truck drivers believe in the benefits of current lane restrictions, but tractor semi-trailer drivers do not.*

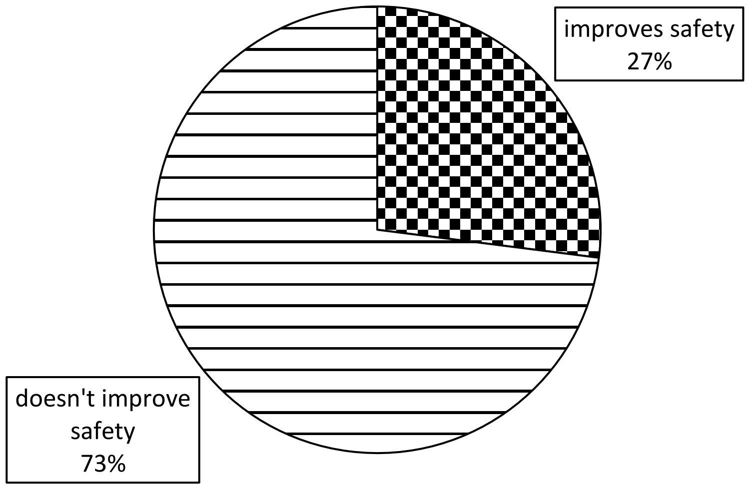


Figure 115
Tractor semi trailer drivers' opinions on lane restriction

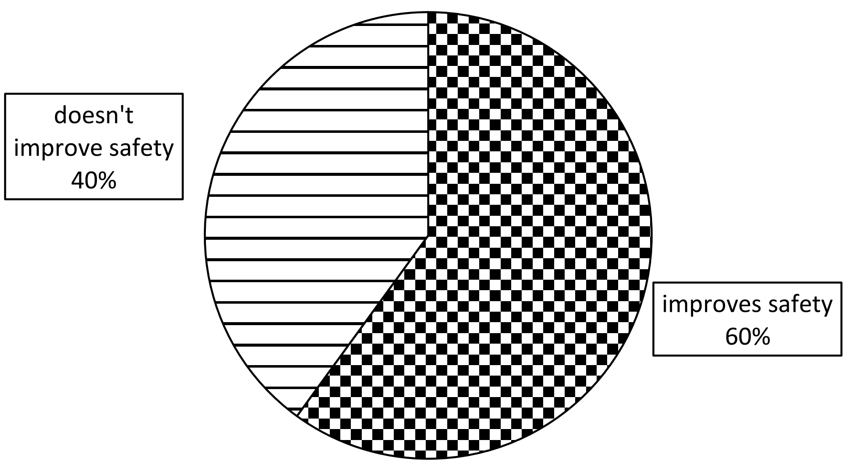


Figure 116
Other truck drivers' opinions on lane restriction

6. What is the percentage of drivers that are aware of both lane restriction and speed limit policies?

Figure 117 shows that 94 percent of the drivers (or 154 out of 159) are aware of both speed limit and lane restriction policies.

- *This finding suggests that almost all of the drivers pay attention to the roadway signs and the signs are legible and understandable.*

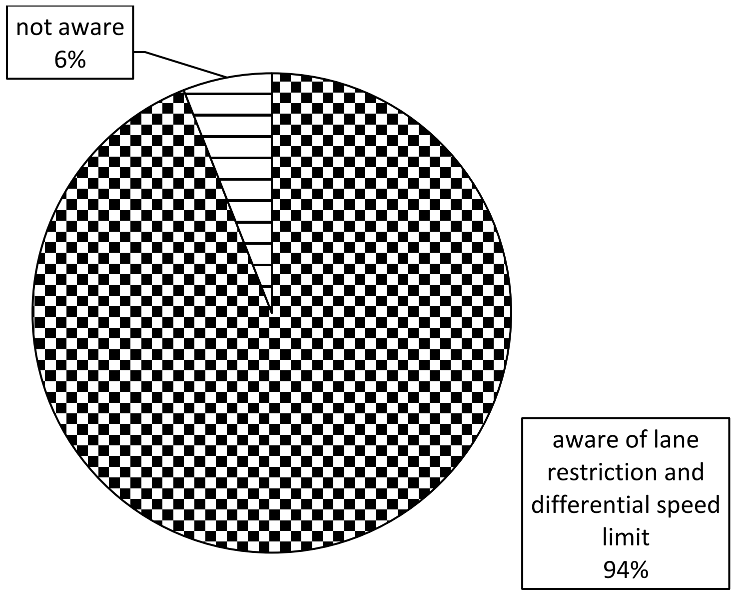


Figure 117
Policy awareness

7. What is the percentage of the drivers who are aware of the speed limit think that there is adequate warning and the signs are legible?

As shown in Figure 118, 82 percent of the drivers who are aware of the current speed limit (or 126 out of 153) think that there is adequate warning and the signs are legible.

- *Like the previous findings, this finding suggests that the speed limit signs already in place are legible and understandable.*

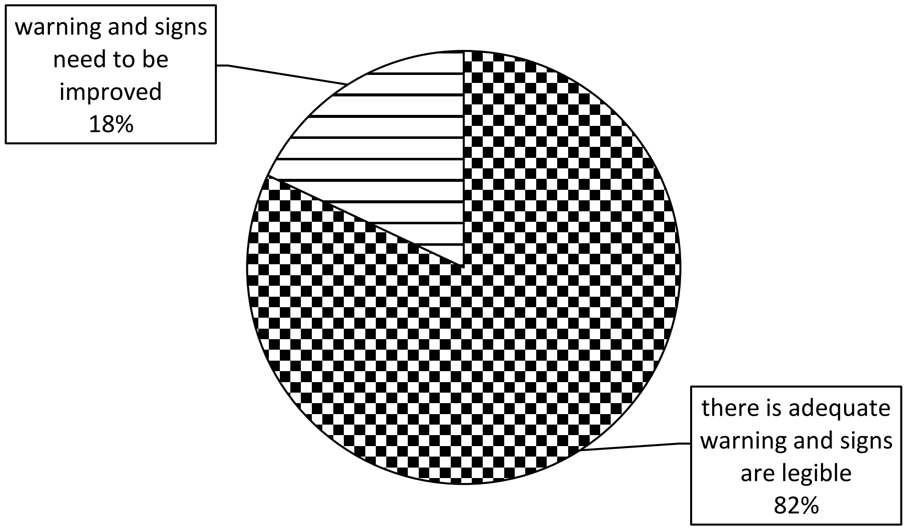


Figure 118
Opinions of drivers who are aware of the differential speed limit policy

8. What is the percentage of the drivers who are aware of the lane restriction think that there is adequate warning and the signs are legible?

The majority of the drivers are happy with the roadway signs and warning for the lane restriction. The figure shows that 83 percent of the drivers who are aware of the current lane restriction (or 126 out of 151) think that there is adequate warning and the signs are legible (Figure 119).

- *Like the previous findings, this finding suggests that the lane restriction signs and warning are also legible and understandable.*

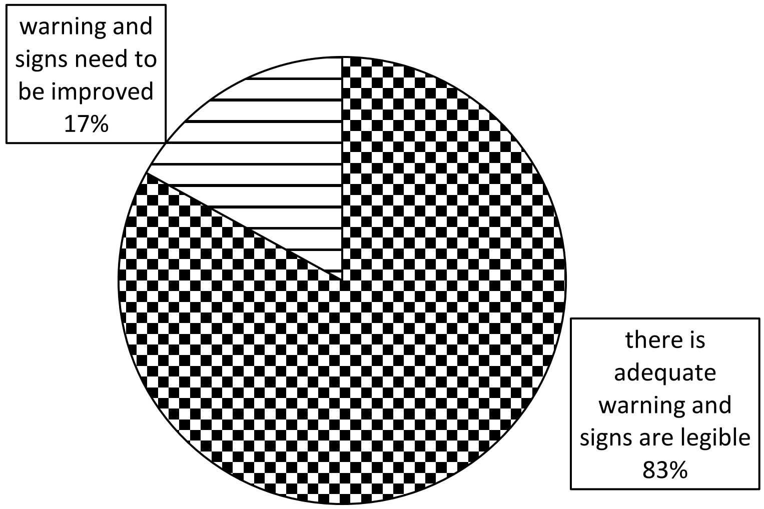


Figure 119
Opinions of drivers who are aware of the lane restriction policy

9. What is the percentage of drivers that are in favor of keeping both speed limit and lane restriction policies in force?

The survey responses suggest that about 9 percent of drivers (or 14 out of 157) are in favor of keeping both of the current policies in force. This is illustrated by Figure 120.

- *A very low acceptance rate is surprising when compared to the percentage of small truck drivers who think the current speed and lane policies improve safety. This suggests that either the percentage of small truck drivers in the sample is low or the truck drivers prefer operational benefits of a policy over its safety benefits.*

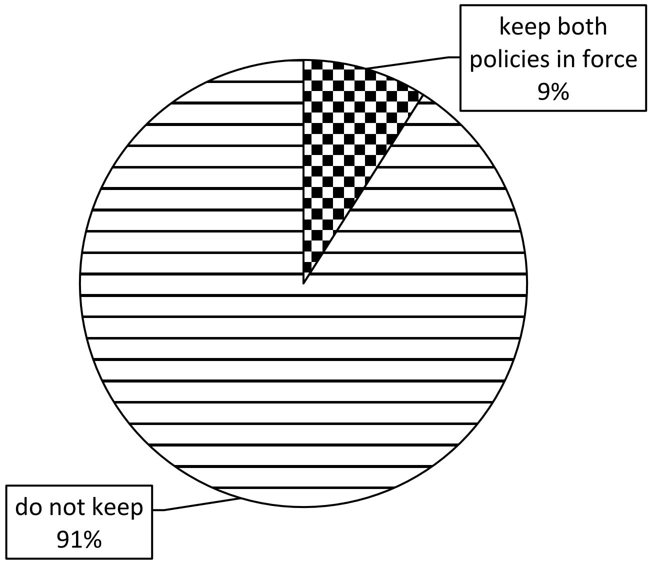


Figure 120
Opinions on keeping the restrictions in force

Chi-Square Test of Independence

Responses to some questions in the survey questionnaire might determine the way other questions are answered. In order to find out whether such relations exist among the responses, a chi-square test of independence is performed.

The procedure includes forming tables for the actual number of responses to specific questions in the survey data, expected number of responses, and the chi-square values. The formula for the expected number of responses is

$$E_{ij} = (T_i \, x \, T_j) \, / \, N \qquad (10)$$

where E_{ij} is the expected number of responses for the cell in the i^{th} row and the j^{th} column of Table 24, T_i is the total number of responses in the i^{th} row, T_j is the total number of responses in the j^{th} column, and N is the total number of responses on the whole table.

Cell chi-square values are calculated using the following formula:

$$\chi^2_{ij} = \frac{(E_{ij} - O_{ij})^2}{E_{ij}} \qquad (11)$$

where, χ^2_{ij} is the chi-square value for the cell in the i^{th} row and the j^{th} column of Table 25, and O_{ij} is the actual number of responses for the cell in the i^{th} row and the j^{th} column of Table 23.

Chi-square is the sum of all cell chi-square values:

$$\chi_{ij}^2 = \sum \chi_{ij}^2 \tag{12}$$

Given the chi-square value, the corresponding p value of associated degree of freedom will be determined from the standard table. If the responses to the questions are associated in some way, then the p-value will less than 0.05 (using a 5 percent significance level); otherwise, the p value will be larger than 0.05. For a two-way table with i rows and j columns, the associated degree of freedom is (i-1) × (j-1). Further, by looking at the chi-square value of each cell, the response that contributes most to the association will be determined.

Following is the application of this test to the Atchafalaya Truck Driver Questionnaire responses. For each question, a conclusion was drawn from the test results; 95 percent confidence interval and margin of error are computed.

Question 1: Does the respondent's support with the 55 mph truck speed limit depend on how often he travels over the Atchafalaya Swamp Freeway?

Table 23
Actual number of responses to frequency of travel over the section and support with the continuation of 55 mph truck speed limit

	Keep 55	Do not keep 55	Total
Frequency of travel>100	8	42	50
Frequency of travel<100	15	32	47
Total	23	74	97

Table 24
Expected number of responses

	Keep 55	Do not keep 55
Frequency of travel>100	11.856	38.144
Frequency of travel<100	11.144	35.856

Table 25

Cell chi-square values

	Keep 55	Do not keep 55
Frequency of travel>100	1.254	0.390
Frequency of travel<100	1.334	0.415

p-value =0.065503624

The threshold for the frequency of travel is determined as 100 by taking the second quartile of the frequency of travel dataset.

Conclusion: As concluded from Table 25, truck drivers' support with the 55 mph speed limit does not depend on how often they travel over the Atchafalaya Swamp Freeway. Drivers who have traveled more than 100 times in the last 4 years tend to reject the 55 mph truck speed limit practice. The independency between the drivers who have traveled fewer than 100 times in the last 4 years and the drivers that support the 55 mph speed limit is the critical contributor to the overall independency. Below are the sample statistics for this analysis.

Table 26

Sample statistics

sample size	97
keep 55	23
do not keep 55	74
confidence level	0.95
ps	0.237
z	1.960
standard error	0.043
margin of error	0.085
lower confidence interval	0.152
upper confidence interval	0.322

Question 2: Does the respondent's support with the lane restriction depend on how often he travels over the Atchafalaya Swamp Freeway?

Table 27

Actual number of responses to frequency of travel over the section and support with the continuation of lane restriction

	Keep the lane restriction	Lift the lane restriction	Total
Frequency of travel>100	9	41	50
Frequency of travel<100	12	35	47
Total	21	76	97

Table 28

Expected number of responses

	Keep the lane restriction	Lift the lane restriction
Frequency of travel>100	10.825	39.175
Frequency of travel<100	10.175	36.825

Table 29

Cell chi-square values

	Keep the lane restriction	Lift the lane restriction
Frequency of travel>100	0.308	0.085
Frequency of travel<100	0.327	0.090

p-value = 0.36804719

The threshold for the frequency of travel is determined as 100 by taking the second quartile of the frequency of the travel dataset.

Conclusion: It is inferred from Table 29 that truck drivers' support with the lane restriction does not depend on how often they travel over the Atchafalaya Swamp Freeway. Drivers that have traveled more than 100 times in the last 4 years tend to reject the lane restriction practice. The independency between the drivers that travel fewer than 100 times in the last 4 years and the drivers that support the lane restriction is the critical contributor to the overall independency. The sample statistics are presented in Table 32.

Table 30
Sample statistics

sample size	97
keep lane restriction	21
lift lane restriction	76
confidence level	0.95
ps	0.216
Z	1.960
standard error	0.042
margin of error	0.082
lower confidence interval	0.135
upper confidence interval	0.298

Question 3: Does the respondent's support with the 55/60 mph differential speed limit depend on how often he travels over the Atchafalaya Swamp Freeway?

Table 31
Actual number of responses to frequency of travel over the section and support with the continuation of differential speed limit

	Keep 55/60	Do not keep 55/60	Total
Frequency of travel>100	3	47	50
Frequency of travel<100	9	38	47
Total	12	85	97

Table 32
Expected number of responses

	Keep 55/60	Do not keep 55/60
Frequency of travel>100	6.186	43.814
Frequency of travel<100	5.814	41.186

Table 33
Cell chi-square values

	Keep 55/60	Do not keep 55/60
Frequency of travel>100	1.641	0.232
Frequency of travel<100	1.745	0.246

p-value = 0.049336898

The threshold for the frequency of travel is determined as 100 by taking the second quartile of the frequency of travel dataset.

Conclusion: Truck drivers' support with the 55/60 mph differential speed limit depends on how often they travel over the Atchafalaya Swamp Freeway, as inferred from Table 33. Drivers that have traveled more than 100 times in the last 4 years tend to reject the 55/60 mph truck speed limit practice. This relation is the critical contributor to the overall dependency. The highest independency is between the drivers that have traveled fewer than 100 times in the last 4 years and the drivers that support the 55/60 mph differential speed limit. Table 34 lists the sample statistics.

Table 34
Sample statistics

sample size	97
keep 55/60	12
do not keep 55/60	85
confidence level	0.95
ps	0.124
z	1.960
standard error	0.033
margin of error	0.066
lower confidence interval	0.058
upper confidence interval	0.189

Question 4: Does the respondent's support with the 55/60 mph differential speed limit depend on the speed limit's safety effects?

Table 35
Actual number of responses to impact of 55/60 mph speed limit on safety and support with the continuation of 55/60 mph speed limit

	Keep 55/60	Do not keep 55/60	Total
55/60 improves safety	18	31	49
55/60 reduces safety	2	86	88
Total	20	117	137

Table 36
Expected number of responses

	Keep 55/60	Do not keep 55/60
55/60 improves safety	7.153	41.847
55/60 reduces safety	12.847	75.153

Table 37
Cell chi-square values

	Keep 55/60	Do not keep 55/60
55/60 improves safety	16.447	2.811
55/60 reduces safety	9.158	1.565
p-value = 4.36029E-08		

Conclusion: Table 37 suggests that the 55/60-mph differential speed limit's impact on traffic safety is a driving factor in the support with the differential speed limit. Drivers that think a 55/60-mph differential speed limit reduces safety tend to reject the 55/60-mph truck speed limit practice. It can be concluded that a reason for rejecting the 55/60-mph speed limit practice is the reduction of safety caused by the speed limit. This relation is the critical contributor to the overall dependency. The highest independency is between the drivers that think the 55/60-mph differential speed limit improves safety and the drivers that are in favor of keeping that speed limit. Next are the sample statistics.

Table 38
Sample statistics

sample size	137
keep 55/60	20
do not keep 55/60	117
confidence level	0.95
ps	0.146
z	1.960
standard error	0.030
margin of error	0.059
lower confidence interval	0.087
upper confidence interval	0.205

Question 5: Does the respondent's support with the lane restriction depend on the lane restriction's safety effects?

Table 39

Actual number of responses to impact of lane restriction on safety and support with the continuation of lane restriction

	Keep lane restriciton	Lift lane restriction	Total
Lane restriction improves safety	28	24	52
Lane restriction reduces safety	3	86	89
Total	31	110	141

Table 40

Expected number of responses

	Keep lane restriction	Lift lane restriction
Lane restriction improves safety	11.433	40.567
Lane restriction reduces safety	19.567	69.433

Table 41

Cell chi-square values

	Keep lane restriction	Lift lane restriction
Lane restriction improves safety	24.008	6.766
Lane restriction reduces safety	14.027	3.953
p-value = 2.90053E-12		

Conclusion: The conclusion drawn from Table 41 is that the impact of the lane restriction on traffic safety is a factor that was taken into consideration by truck drivers when supporting that restriction. Drivers that think the lane restriction reduces safety tend to reject it. It can be concluded that a reason for rejecting the lane restriction practice is the reduction of safety caused by the speed limit. This relation is the critical contributor to the overall dependency. The highest independency is between the drivers that think the lane restriction improves safety and the drivers that are in favor of keeping the lane restriction. Sample statistics are presented below.

Table 42
Sample statistics

sample size	141
keep 55/60	31
do not keep 55/60	110
confidence level	0.95
ps	0.220
z	1.960
standard error	0.035
margin of error	0.068
lower confidence interval	0.151
upper confidence interval	0.288

Question 6: Do the lane restriction's safety effects influence the need for the 55/60-mph differential speed limit application?

Table 43
Actual number of responses to impact of lane restriction on safety and support with the continuation of 55/60-mph speed limit

	Keep 55/60	Do not keep 55/60	Total
Lane restriction improves safety	20	32	52
Lane restriction reduces safety	2	87	89
Total	22	119	141

Table 44

Expected number of responses

	Keep 55/60	Do not keep 55/60
Lane restriction improves safety	8.113	43.887
Lane restriction reduces safety	13.887	75.113

Table 45

Cell chi-square values

	Keep 55/60	Do not keep 55/60
Lane restriction improves safety	17.414	3.220
Lane restriction reduces safety	10.175	1.881
p-value = 1.08137E-08		

Conclusion: As deduced from Table 45, the lane restriction's impact on traffic safety is a driving factor in supporting the continuation of the 55/60-mph differential speed limit practice. Drivers that think the lane restriction reduces safety tend to reject the practice of the 55/60-mph differential speed limit. This relation is the critical contributor to the overall dependency. The highest independency is between the drivers that think the lane restriction improves safety and the drivers that are in favor of keeping the 55/60-mph differential speed limit. Sample statistics are as such:

Table 46

Sample statistics

sample size	141
keep 55/60	22
do not keep 55/60	119
confidence level	0.95
ps	0.156
z	1.960
standard error	0.031
margin of error	0.060
lower confidence interval	0.096
upper confidence interval	0.216

Question 7: Does the type of truck that the respondent drives influence his opinion about the impact of the 55/60 mph differential speed limit on traffic safety?

Table 47

Actual number of responses to type of truck operated and impact of 55/60-mph speed limit on safety

	55/60 improves safety	55/60 reduces safety	Total
Small truck	15	7	22
18-wheeler	30	73	103
Total	45	80	125

Table 48

Expected number of responses

	55/60 improves safety	55/60 reduces safety
Small truck	7.92	14.08
18-wheeler	37.08	65.92

Table 49

Cell chi-square values

	55/60 improves safety	55/60 reduces safety
Small truck	6.329	3.560
18-wheeler	1.352	0.760

p-value = 0.000531588

Conclusion: According to the cell chi-square values previously obtained, the type of truck the respondent drives influences his opinion about the impact of the 55/60-mph differential speed limit on traffic safety. Drivers in 18-wheelers tend to think that the 55/60-mph differential speed limit reduces safety. This relation is the critical contributor to the overall dependency. The highest independency is between the small truck drivers and the drivers that think the 55/60-mph differential speed limit improves safety. Sample statistics are as follows:

Table 50

Sample statistics

sample size	125
55/60 improves safety	45
doesn't improve	80
confidence level	0.95
ps	0.36
z	1.960
standard error	0.043
margin of error	0.084
lower confidence interval	0.276
upper confidence interval	0.444

Question 8: Does the respondent's driving experience influence his opinion about the lane restriction's impact on traffic safety?

Table 51

Actual number of responses to driving experience categories and impact of lane restriction on safety

	Lane restriction improves safety	Lane restriction reduces safety	Total
Less than 5 years driving experience	17	13	30
6 to 10 years driving experience	6	12	18
11 to 15 years driving experience	12	20	32
More than 15 years driving experience	17	42	59
Total	52	87	139

Table 52

Expected number of responses

	Lane restriction improves safety	Lane restriction reduces safety
Less than 5 years driving experience	11.223	18.777
6 to 10 years driving experience	6.734	11.266
11 to 15 years driving experience	11.971	20.028
More than 15 years driving experience	22.072	36.928

Table 53
Cell chi-square values

	Lane restriction improves safety	Lane restriction reduces safety
Less than 5 years driving experience	2.974	1.777
6 to 10 years driving experience	0.080	0.048
11 to 15 years driving experience	6.91754E-05	4.13462E-05
More than 15 years driving experience	1.165	0.697
p-value = 0.080627519		

Conclusion: Table 53 suggests that respondents' driving experience doesn't influence their opinion about the impact of the lane restriction on traffic safety. Drivers with 11 to 15 years driving experience tend to think that the lane restriction reduces safety. The highest independency is between the drivers with less than 5 years of experience and the drivers that think lane restriction improves safety. This is the critical contributor to the overall independency. Below are the sample statistics.

Table 54
Sample statistics

sample size	139
lane rest. improves safety	52
lane rest. doesn't improve	87
confidence level	0.95
ps	0.374
z	1.960
standard error	0.041
margin of error	0.080
lower confidence interval	0.294
upper confidence interval	0.455

Question 9: Does the respondent's driving experience influence his opinion about the impact of the 55/60-mph differential speed limit on traffic safety?

Table 55
Actual number of responses to driving experience categories and impact of 55/60-mph speed limit on safety

	Speed restriction improves safety	Speed restriction reduces safety	Total
Less than 5 years driving experience	17	12	29
6 to 10 years driving experience	7	11	18
11 to 15 years driving experience	11	20	31
More than 15 years driving experience	14	43	57
Total	49	86	135

Table 56
Expected number of responses

	Speed restriction improves safety	Speed restriction reduces safety
Less than 5 years driving experience	10.526	18.474
6 to 10 years driving experience	6.533	11.467
11 to 15 years driving experience	11.252	19.748
More than 15 years driving experience	20.689	36.311

Table 57
Cell chi-square values

	Speed restriction improves safety	Speed restriction reduces safety
Less than 5 years driving experience	3.982	2.269
6 to 10 years driving experience	0.033	0.019
11 to 15 years driving experience	0.006	0.003
More than 15 years driving experience	2.163	1.232

p-value = 0.021231729

Conclusion: As inferred from the table above, respondents' driving experience influences their opinion about the impact of the 55/60-mph differential speed limit on traffic safety. Drivers with 11 to 15 years of experience tend to think that the 55/60 mph differential speed limit reduces safety. This relation is the critical contributor to the overall dependency. The highest independency is between the drivers with less than 5 years driving experience and the drivers that think the 55/60-mph differential speed limit improves safety. Table 58 presents the sample statistics.

Table 58
Sample statistics

sample size	135
speed rest. improves safety	49
speed rest. doesn't improve	86
confidence level	0.95
ps	0.363
z	1.960
standard error	0.041
margin of error	0.081
lower confidence interval	0.282
upper confidence interval	0.444

Canonical Correlation

Canonical correlation is a multivariate analysis method, which tests for significant linear relationship between a set of predictors and a set of responses. It controls type-I error by considering a set of dependent variables in multidimensional space and accounts for relationship among the dependent variables as well as the relationships between independent variables and dependent variables. Given variable sets of X and Y, canonical correlation analysis is to find the linear combination of each set of variables that is most highly correlated with a linear combination of the other set. These combinations are the first canonical variables. The correlation between each variable and its canonical variable is useful to interpret the canonical correlation in terms of the input variables.

$$w_1 = a_1 x_1 + a_2 x_2 + \cdots + a_k x_k \quad (13)$$

$$v_1 = b_1 y_1 + b_2 y_2 + \cdots + b_p y_p \quad (14)$$

In the survey analysis, the questions were classified into two groups: behavior and opinion. The classification is shown in Table 59. The SAS CANCORR procedure was used to perform the canonical correlation analysis between behavior questions and opinion questions. The variable B3 (Q3) was removed from the analysis due to large number of missing responses. The threshold was set at 0.3 to select input variables that contribute significantly to the canonical correlation. Further, the SAS CORR procedure was used to calculate the linear correlation between each behavior and opinion question.

Table 60 presents the results for the tests of canonical correlation between behavior questions and opinion questions. It shows that only the first canonical correlation is significant at a 0.05 significance level.

Table 61 shows the correlation values between the behavior and their canonical variables. Based on a minimum correlation threshold of 0.3, B1, B5, B6, and B11 were identified as the input variables that contribute most to the canonical correlation. Similarly, Table 62 shows that O2, O3, and O5-O8 are the opinion variables that contribute most to the canonical correlation.

The selection results on behavior variables indicate that the longer a truck driver works, the more aware he is of the restrictions on trucks and less likely to receive citation for violation of the restrictions. In addition, it shows that to avoid accidents or hazards in the right lane is the main reason for truck drivers to change lanes. The results on opinion variables present two opposite opinions. The respondents who support the currently implemented DSL and right lane restriction are pleased with the current speed limit for trucks, and they believe the restrictions are helpful to improve safety. However, according to responses of those who support the restrictions, there are not sufficient warnings of the DSL and right lane restriction.

Table 59
Classification of survey questions

Group	Questions
Behavior	B1 = 'Q1-years working as a truck driver' B2 = 'Q2-type of vehicle' B3 = 'Q3-frequency of travel over the Atchafalaya section' B4 = 'Q4-awareness of differential speed limit' B5 = 'Q5-awareness of right lane restriction' B6 = 'Q10- received citation for violation of speed limit' B7 = 'Q 11-received citation for violation of lane restriction' B8 = '12a- change lane because of broken down car, state trooper, emergency vehicle' B9 = '12b- change lane to pass slow vehicles' B10 = '12c- change lane to exit freeway' B11 = '12d- change lane to avoid accident or hazard in right lane' B12 = '12e- change lane because of construction and highway workers' B13 = '12f- change lane to get a better view' B14 = '12g- change lane for other reasons'
Opinion	O1 = 'Q6-current speed limit improves safety' O2 = 'Q7-current truck lane restriction improves safety' O3 = 'Q8-sufficient warning of the DSL and truck lane restriction' O4 = 'Q9- legibility of the warning signs is adequate' O5 = 'Q13a- keep the 55mph speed limit for trucks' O6 = 'Q13b- keep the 60 mph speed limit of cars' O7 = 'Q13c- keep the lane restriction' O8 = 'Q 13d-change the speed limit for trucks' O9 = 'Q13e-change the speed limit for cars' O10 = 'Q13fl-speed limit for left lane' O11 = 'Q13fr-speed limit for right lane' O12 = 'Q13g - reduce speed limit for all vehicles during peak hour' O13 = 'Q13h- place a mechanism to detect incidents' O14 = 'Q13i-place a mechanism to inform the cruising speed' O15 = 'Q13j-double the fines for speed and lane violations' O16 = 'Q13k-restrict trucks to the left lane and allow them to change lane at exits' O17 = 'Q13l- restrict cars to the left lane and allow them to change lane at exits' O18 = 'Q13m- restrict cars to the right lane' O19 = 'Q13n- restrict trucks to the lane that it was at the beginning of the section' O20 = 'Q13o- restrict cars to the lane that it was at the beginning of the section' O21 = 'Q13p-no restrictions for trucks' O22 = 'Q13q- separate left lane from right lane with barriers' O23 = 'Q13r-improve the lighting along the section' O24 = 'Q 13s- increase the number of law enforcement patrols';

Table 60
Tests for canonical correlation

	Test of H_0: The canonical correlations in the current row and all that follow are zero				
	Likelihood Ratio	Approximate F Value	Num DF	Den DF	Pr > F
1	0.060	1.25	312	1404.8	0.005
2	0.109	1.10	276	1315.3	0.150
3	0.182	0.95	242	1223.6	0.677
4	0.264	0.85	210	1129.5	0.930
5	0.352	0.77	180	1033	0.984
6	0.453	0.69	152	933.6	0.998
7	0.560	0.61	126	831.16	1.000
8	0.672	0.51	102	725.32	1.000
9	0.758	0.46	80	615.69	1.000
10	0.827	0.42	60	501.88	1.000
11	0.894	0.35	42	383.44	1.000
12	0.948	0.27	26	260	1.000
13	0.983	0.19	12	131	0.999

To further investigate the relationship between individual behavior and opinion variables, the linear correlation between each behavior and opinion questions were computed using SAS PROC CORR procedure; the results shown in Table 63 present the linear correlation. There were 17 significant correlations found at the 95 percent level of significance. Most of the correlations are related to the selected variables in CANCORR procedure. The positive coefficient means positive linear correlation, while the negative coefficient means negative linear correlation.

Based on the correlation analysis results, researchers learned that the truck drivers with more driving experience are opposed to the currently applied DSL and right lane restriction for trucks. Moreover, it shows that the lane change behavior has significant effect on the opinion of the truck restrictions. Those who change lanes mainly for passing the slow vehicles are not in favor of keeping the 55-mph speed limit for trucks, and they prefer no restriction on trucks. Those who change lanes to avoid accidents or hazards in the right lane think right lane restrictions for trucks can improve safety, and they are in favor of keeping the 55-mph speed limit for trucks.

Table 61

Correlations between the behavior and their canonical variables

		BEH1	BEH2	BEH3	BEH4	BEH5	BEH6	BEH7	BEH8	BEH9
B1	Q1-years working as a truck driver	-0.429	0.262	-0.465	0.391	-0.039	0.225	0.078	-0.492	-0.133
B2	Q2-type of vehicle	-0.255	0.018	-0.372	0.263	0.369	0.059	-0.665	0.191	0.176
B4	Q4-awareness of differential speed limit	-0.198	0.536	0.165	0.208	-0.160	-0.027	0.033	0.437	0.131
B5	Q5-awareness of right lane restriction	-0.360	0.550	0.337	-0.309	-0.156	0.260	-0.068	0.200	0.081
B6	Q10- received citation for violation of speed limit	0.370	0.023	-0.049	-0.110	0.339	-0.009	-0.271	-0.335	0.435
B7	Q 11-received citation for violation of lane restriction	0.047	-0.259	-0.184	0.041	-0.158	-0.321	-0.089	-0.145	0.456
B8	12a- change lane because of stalled/emergency/police vehicle	0.154	0.295	-0.181	0.047	-0.231	0.078	0.074	-0.173	0.232
B9	12b- change lane to pass slow vehicles	-0.152	-0.242	0.139	0.141	-0.448	0.247	-0.458	-0.097	-0.245
B10	12c- change lane to exit freeway	0.036	-0.022	-0.176	0.228	0.455	-0.229	0.157	0.253	-0.546
B11	12d- change lane to avoid accident or hazard in right lane	0.565	0.213	0.020	0.475	-0.164	0.231	0.036	0.154	0.051
B12	12e- change lane because of construction and highway workers	0.051	0.409	0.177	0.403	0.093	-0.114	0.230	-0.165	0.219
B13	12f- change lane to get a better view	-0.169	-0.469	0.051	0.108	0.181	0.521	0.318	0.139	0.403
B14	12g- change lane for other reasons	0.168	0.036	-0.487	-0.428	-0.106	0.326	0.273	0.317	-0.024

Table 62

Correlations between the opinion and their canonical variables

		OPI1	OPI2	OPI3	OPI4	OPI5	OPI6	OPI7	OPI8
O1	Q6-current speed limit improves safety	0.173	0.377	0.064	-0.127	0.075	-0.123	-0.115	0.38
O2	Q7-current truck lane restriction improves safety	0.357	0.348	-0.005	-0.041	0.03	-0.057	0.113	0.185
O3	Q8-sufficient warning of the DSL and truck lane restriction	-0.314	0.44	0.524	-0.205	-0.096	0.168	0.055	0.074
O4	Q9- legibility of the warning signs is adequate	-0.115	0.348	0.358	0.029	-0.065	0.247	0.303	0.287
O5	Q13a- keep the 55mph speed limit for trucks	0.428	0.244	0.404	0.15	0.214	-0.28	0.2	0.01
O6	Q13b- keep the 60 mph speed limit of cars	0.467	-0.057	0.536	0.023	-0.006	-0.105	0.19	-0.296
O7	Q13c- keep the lane restriction	0.385	0.292	0.303	0.149	-0.008	-0.044	0.042	-0.003
O8	Q 13d-change the speed limit for trucks	-0.438	-0.453	0.174	0.236	0.322	0.325	-0.094	0.055
O9	Q13e-change the speed limit for cars	-0.048	-0.309	0.008	-0.089	-0.042	0.699	0.157	0.21
O10	Q13fl-speed limit for left lane	0.036	-0.033	0.063	-0.328	-0.198	0.044	-0.031	-0.145
O11	Q13fr-speed limit for right lane	-0.071	-0.102	-0.171	-0.445	0.164	-0.067	0.075	0.02
O12	Q13g - reduce speed limit for all vehicles during peak hour	0.116	0.211	-0.122	0.507	0.133	-0.245	0.268	0.009
O13	Q13h- place a mechanism to detect incidents	0.133	0.185	-0.055	0.346	-0.479	0.046	-0.258	-0.283
O14	Q13i-place a mechanism to inform the cruising speed	0.146	-0.029	-0.068	0.222	-0.149	-0.038	-0.007	-0.291
O15	Q13j-double the fines for speed and lane violations	0.079	0.156	-0.02	-0.066	-0.171	-0.146	0.34	-0.124
O16	Q13k-restrict trucks to the left lane and allow them to change lane at exits	-0.07	0.009	-0.133	0.067	0.231	-0.294	-0.001	-0.019
O17	Q13l- restrict cars to the left lane and allow them to change lane at exits	0.047	0.193	0.106	-0.024	-0.153	-0.084	0.27	-0.102
O18	Q13m- restrict cars to the right lane	0.024	-0.056	0.23	-0.106	-0.083	-0.102	-0.313	0.322
O19	Q13n- restrict trucks to the lane that it was at the beginning of the section	-0.222	0.062	0.076	0.067	0.113	0.049	0.121	-0.1
O20	Q13o- restrict cars to the lane that it was at the beginning of the section	-0.138	0.023	0.028	-0.116	0.062	-0.13	-0.202	0.149
O21	Q13p-no restrictions for trucks	-0.232	-0.203	-0.001	0.123	-0.068	0.486	-0.355	-0.081
O22	Q13q- separate left lane from right lane with barriers	0.274	0.318	0.073	-0.006	0.349	0.166	-0.255	-0.296
O23	Q13r-improve the lighting along the section	0.28	-0.026	-0.094	-0.014	-0.077	-0.197	-0.13	0.037
O24	Q 13s- increase the number of law enforcement patrols	0.178	0.39	-0.063	0.094	-0.006	-0.057	0.102	-0.266

Table 63
Linear correlation between behavior and opinion

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
O1	-0.121	0.027	0.061	0.150	0.131	0.053	-0.048	-0.103	-0.103	-0.012	0.088	0.101	-0.131	0.063
Q1-current speed limit improve safety	0.133	0.733	0.449	0.060	0.103	0.510	0.548	0.200	0.200	0.879	0.273	0.209	0.103	0.436
	156	157	156	157	157	157	157	157	157	157	157	157	157	157
O2	-0.091	-0.068	-0.045	0.071	0.064	0.048	-0.055	-0.124	-0.124	0.062	0.202	0.12	-0.145	0.084
Q7-right lane restriction improve safety	0.259	0.398	0.580	0.378	0.424	0.552	0.494	0.123	0.123	0.439	0.011	0.135	0.07	0.296
	156	157	156	157	157	157	157	157	157	157	157	157	157	157
O3	-0.008	-0.059	0.054	0.269	0.443	-0.102	-0.145	0.034	0.034	-0.07	-0.044	0.096	-0.053	-0.09
Q8-sufficient warning of the DSL and right lane restriction	0.923	0.458	0.505	0.001	<.0001	0.200	0.068	0.674	0.674	0.38	0.585	0.232	0.507	0.258
	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O4	0.003	-0.082	-0.157	0.285	0.304	-0.110	-0.154	-0.010	-0.010	0.005	0.062	0.091	0.017	-0.008
Q9- legibility of the warning sign is adequate	0.972	0.306	0.049	0.000	0.000	0.170	0.053	0.904	0.904	0.946	0.441	0.255	0.829	0.919
	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O5	-0.197	-0.126	-0.038	0.032	-0.009	0.071	-0.059	-0.175	-0.175	0.026	0.234	0.244	-0.128	-0.11
Q13a- keep the 55mph speed limit for trucks	0.014	0.115	0.641	0.693	0.914	0.375	0.459	0.028	0.028	0.744	0.003	0.002	0.11	0.169
	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O6	-0.227	-0.251	-0.081	-0.05	-0.081	0.073	-0.058	-0.003	-0.003	-0.044	0.137	0.103	-0.057	-0.108
Q13b- keep the 60 mph speed limit of cars	0.005	0.002	0.312	0.533	0.312	0.359	0.467	0.969	0.969	0.586	0.087	0.198	0.48	0.177
	156	158	157	158	158	158	158	158	158	158	158	158	158	158

Table 63

Linear correlation between behavior and opinion (continued)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
O7 Q13c- keep the lane restriction	-0.101 0.209 156	0.034 0.676 158	-0.018 0.828 157	0.024 0.766 158	0.022 0.782 158	-0.003 0.974 158	-0.013 0.872 158	-0.109 0.173 158	-0.109 0.173 158	-0.02 0.804 158	-0.024 0.761 158	-0.008 0.921 158	-0.028 0.729 158	-0.024 0.766 158
O8 Q 13d-change the speed limit for trucks	0.070 0.386 156	0.152 0.056 158	-0.072 0.368 157	-0.042 0.603 158	-0.007 0.932 158	-0.058 0.471 158	-0.003 0.968 158	0.143 0.074 158	0.143 0.074 158	0.067 0.401 158	-0.147 0.066 158	-0.11 0.169 158	0.298 0 158	-0.149 0.062 158
O9 Q13e-change the speed limit for cars	-0.025 0.753 156	0.001 0.991 158	-0.035 0.661 157	-0.071 0.379 158	0.037 0.644 158	-0.053 0.507 158	-0.050 0.529 158	0.083 0.299 158	0.083 0.299 158	-0.063 0.431 158	0.025 0.757 158	-0.139 0.081 158	0.284 0 158	0.112 0.163 158
O10 Q13fl-speed limit for left lane	-0.083 0.301 156	-0.051 0.522 158	-0.001 0.986 157	-0.088 0.271 158	0.041 0.611 158	-0.020 0.803 158	-0.019 0.813 158	0.019 0.811 158	0.019 0.811 158	-0.153 0.056 158	-0.04 0.619 158	-0.038 0.635 158	-0.041 0.611 158	0.027 0.741 158
O11 Q13fr-speed limit for right lane	-0.049 0.544 156	-0.044 0.586 158	0.011 0.892 157	-0.045 0.575 158	-0.013 0.868 158	0.007 0.935 158	0.006 0.939 158	0.086 0.284 158	0.086 0.284 158	0.044 0.587 158	0.001 0.992 158	-0.019 0.816 158	0.013 0.868 158	0.045 0.575 158
O12 Q13g - reduce speed limit for all vehicles during peak hour	0.101 0.208 156	0.044 0.583 158	0.023 0.779 157	0.069 0.389 158	-0.106 0.184 158	-0.039 0.624 158	-0.037 0.642 158	-0.102 0.201 158	-0.102 0.201 158	0.124 0.121 158	0.152 0.056 158	0.223 0.005 158	-0.08 0.317 158	-0.069 0.389 158
O13 Q13h- place a mechanism to detects an incidents	0.131 0.102 156	0.032 0.692 158	-0.084 0.295 157	0.084 0.293 158	0.021 0.798 158	-0.010 0.900 158	0.026 0.742 158	0.136 0.089 158	0.136 0.089 158	-0.112 0.162 158	0.194 0.015 158	0.073 0.359 158	-0.136 0.087 158	-0.084 0.293 158
O14 Q13i-place a mechanism to inform the cruising speed	0.047 0.564 156	-0.004 0.958 158	-0.043 0.597 157	-0.037 0.648 158	-0.065 0.419 158	0.064 0.422 158	0.102 0.202 158	0.013 0.869 158	0.013 0.869 158	-0.055 0.496 158	0.135 0.091 158	0.087 0.278 158	-0.002 0.983 158	-0.04 0.622 158

Table 63

Linear correlation between behavior and opinion (continued)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
O15	0.040	-0.135	-0.064	0.069	-0.013	-0.039	-0.037	-0.102	-0.102	-0.075	0.006	0.025	-0.08	0.038
Q13j-double the fines for speed and lane violation	0.620	0.090	0.425	0.389	0.872	0.624	0.642	0.201	0.201	0.351	0.939	0.76	0.317	0.637
	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O16	0.049	0.119	-0.082	-0.033	-0.099	-0.041	-0.038	-0.125	-0.125	0.02	-0.052	0.02	-0.083	-0.071
Q13k-restrick trucks to the left lane and allow them to change lane at exits	0.548	0.138	0.310	0.681	0.216	0.613	0.631	0.118	0.118	0.807	0.514	0.807	0.301	0.374
	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O17	0.009	-0.099	-0.025	0.059	0.069	-0.034	-0.032	0.138	-0.094	-0.064	0.057	0.047	-0.069	-0.059
	0.908	0.217	0.754	0.458	0.388	0.672	0.689	0.083	0.242	0.421	0.477	0.554	0.388	0.458
Q13l- restrict trucks to the left lane and allow them to change lane at exits	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O18	-0.173	0.029	-0.025	0.039	0.046	-0.023	-0.021	-0.051	0.090	-0.043	-0.029	-0.043	-0.046	-0.039
Q13m- restrict cars to the right lane	0.031	0.714	0.759	0.622	0.567	0.779	0.790	0.522	0.263	0.594	0.718	0.594	0.567	0.622
	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O19	0.079	0.036	0.025	0.049	0.057	-0.028	-0.026	-0.009	-0.029	-0.053	-0.068	0.080	0.068	-0.049
Q13n- restrict trucks to the lane that it was at the beginning of the section	0.327	0.650	0.754	0.542	0.479	0.729	0.742	0.914	0.713	0.509	0.393	0.319	0.397	0.542
	156	158	157	158	158	158	158	158	158	158	158	158	158	158
O20	-0.031	0.102	-0.044	0.039	0.046	-0.023	-0.021	0.015	-0.046	-0.043	-0.108	-0.043	-0.046	-0.039
Q13o- restrict cars to the lane that it was at the beginning of the section	0.701	0.202	0.586	0.622	0.567	0.779	0.790	0.850	0.562	0.594	0.177	0.594	0.567	0.622
	156	158	157	158	158	158	158	158	158	158	158	158	158	158

Table 63

Linear correlation between behavior and opinion (continued)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
O21 Q13p-no restrictions for trucks	0.132 0.101 156	0.146 0.068 158	-0.039 0.632 157	-0.031 0.703 158	0.023 0.775 158	-0.097 0.225 158	-0.092 0.250 158	-0.076 0.343 158	0.207 0.009 158	-0.060 0.452 158	-0.039 0.630 158	-0.123 0.125 158	0.094 0.241 158	-0.036 0.649 158
O22 Q13q- separate left lane from right lane with barriers	-0.008 0.923 156	0.077 0.337 158	-0.015 0.856 157	0.043 0.594 158	0.050 0.535 158	0.251 0.002 158	-0.023 0.773 158	0.109 0.173 158	-0.082 0.306 158	-0.046 0.563 158	0.103 0.198 158	0.103 0.197 158	-0.050 0.535 158	-0.043 0.594 158
O23 Q13r-improving the light along the section	-0.089 0.267 156	0.020 0.799 158	-0.114 0.154 157	0.003 0.975 158	-0.055 0.494 158	0.112 0.162 158	0.106 0.185 158	0.052 0.519 158	-0.055 0.493 158	-0.033 0.676 158	0.114 0.154 158	-0.033 0.676 158	-0.061 0.449 158	-0.003 0.975 158
O24 Q 13s- increase the number of law enforcement patrols	0.101 0.210 156	-0.035 0.666 157	0.129 0.109 156	0.120 0.133 157	0.009 0.909 157	0.060 0.458 157	-0.065 0.418 157	0.079 0.325 157	-0.087 0.277 157	-0.061 0.449 -0.064	0.081 0.313 0.057	0.148 0.064 0.047	-0.140 0.080 -0.069	0.030 0.713 -0.059

Online Survey II

The second survey was conducted towards the end of the project in order to seek responses from another sample of trucking companies. Unlike the first survey, this sample was not restricted to companies whose names appeared in the violation records at weigh stations. This survey was also conducted on the LADOTD Web site. The same questionnaire was converted into electronic format and published as a web application. The survey was open online for a period of nearly two months during June and July of 2009. A total of 49 responses were then compiled and the results were summarized and compared to those obtained from the first survey.

PART 1: General Information

(Q1) Truck driving experience: As shown in Figure 121, 61 percent of respondents reported more than 10 years of experience, while 29 percent reported more than 20 years. The respondents with 5 or fewer years of experience amount to 23 percent, among which only 4 percent reported driving experience of one year or less. The second survey results on trucker driving experience appear to be very similar to that of the original survey, which imply that the two samples have similar characteristics in terms of driving experience.

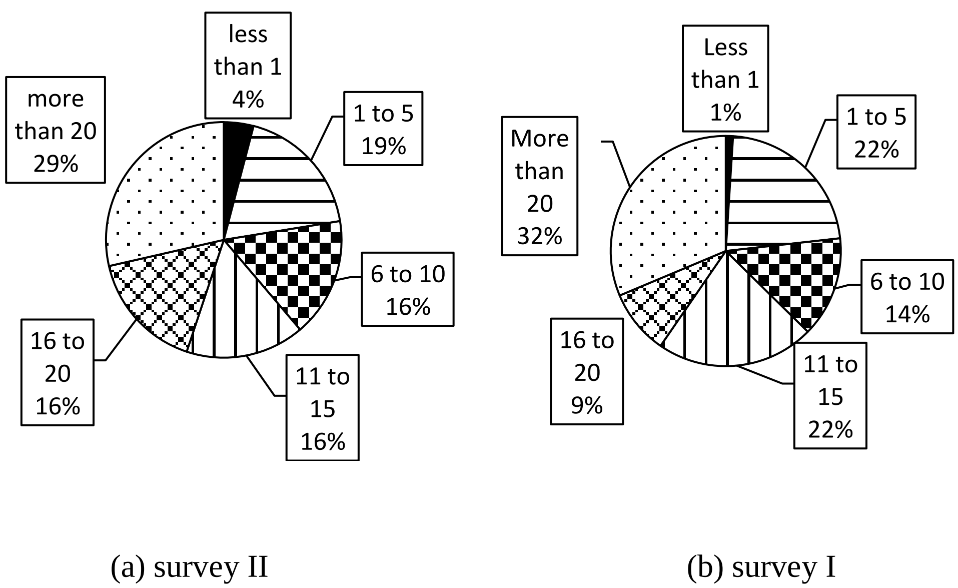
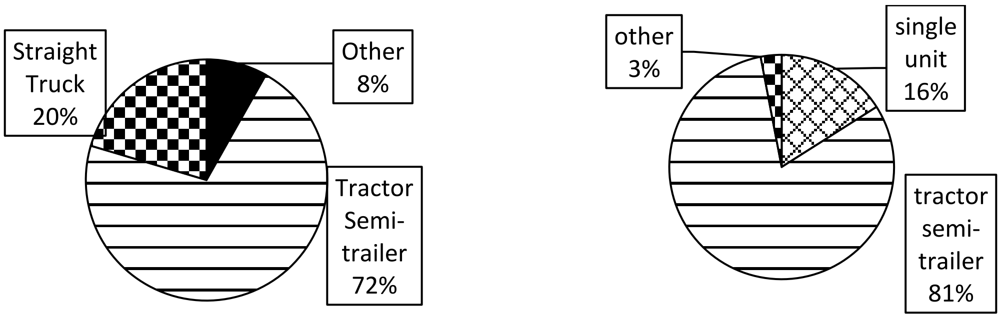


Figure 121
Driving experience for surveys I and II

(Q2) Truck configuration: As shown in Figure 122, more than 70 percent of respondents reported driving a tractor semi-trailer configuration and 20 percent reported driving a single unit “straight” truck. Only 8 percent reported other configurations. These findings are generally consistent with the results of survey I, and suggest that tractor semi-trailer configuration is the most common type of vehicle in the survey. Slight differences may be attributed to the different sample sizes in both surveys.

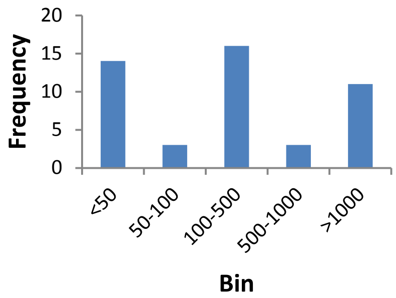


(a) survey II (b) survey I

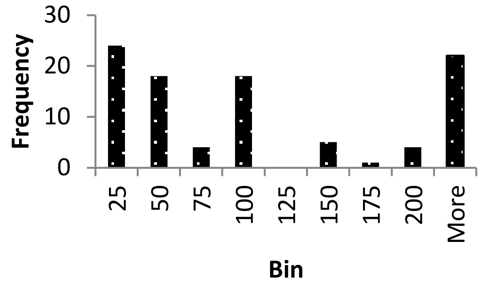
Figure 122
Type of trucks for surveys I and II

PART 2: Atchafalaya Swamp Freeway

(Q3) Frequency of passage over study section: It can be seen from Figure 123 that the majority of the drivers claim to have driven through the study section more than 100 times since the policy was implemented. More specifically, 64 percent of the respondents reported driving more than 500 times, and 23 percent driving the segment even more than 1000 times. Only 29 percent reported driving through the segment 50 or less times since then. Since two years has elapsed since the first survey was completed; the results of the second survey show higher frequency numbers than those obtained in the first survey.



(a) survey II



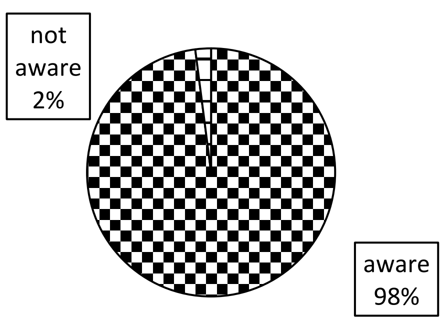
(b) survey I

Figure 123

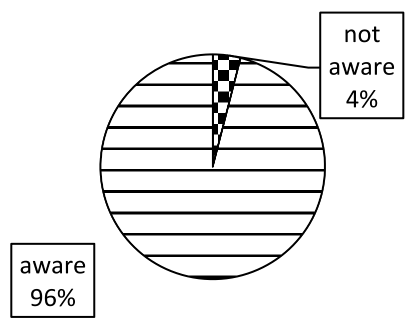
Frequency of travel over the section obtained from survey I and II

PART 3: Policy

(Q4) Awareness of differential speed limits: As shown in Figure 124, most of the respondents, 98 percent, reported being aware of the differential speed limits for cars and trucks. The results are consistent with those of the first survey, and suggest the DSL policy was well understood by the truckers driving along the study segment.



(a) survey II



(b) survey I

Figure 124

55/60-mph differential speed limit awareness from surveys I and II

(Q5) Awareness of truck lane restriction: 96 percent of respondents reported being aware of the truck lane restriction, as shown in Figure 125. The results were consistent with those of the original survey and suggested the truck lane restriction policy was well understood by the truckers driving along the study segment.

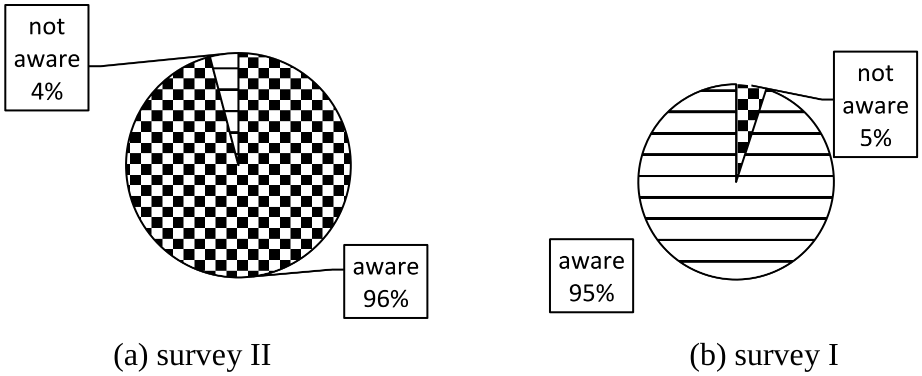
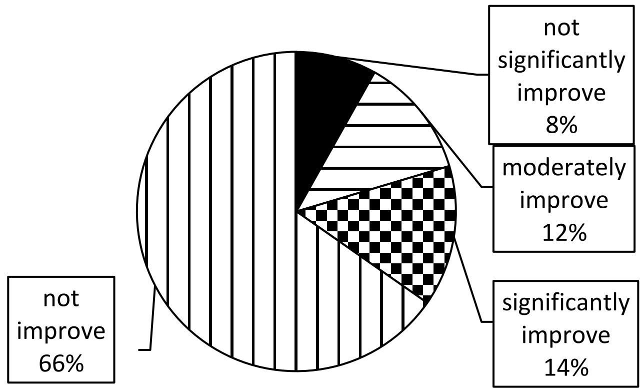


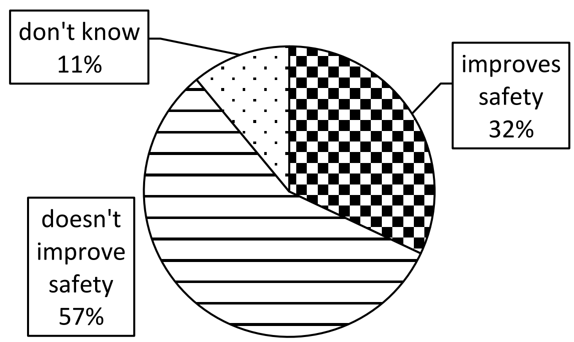
Figure 125
Truck lane restriction awareness from surveys I and II

PART 4: Safety

(Q6) Opinion on the safety benefits of the DSL policy: Figure 126 shows that 66 percent of respondents thought the new policy had no effect on safety. Among the 44 percent who did think the DSL improved safety, 14 percent felt the benefit was very high, and 12 percent thought the benefit was moderate. The results were similar to those of the first survey, indicating that most of the respondents felt the DSL did not benefit freeway safety or that the safety benefits were not as significant.



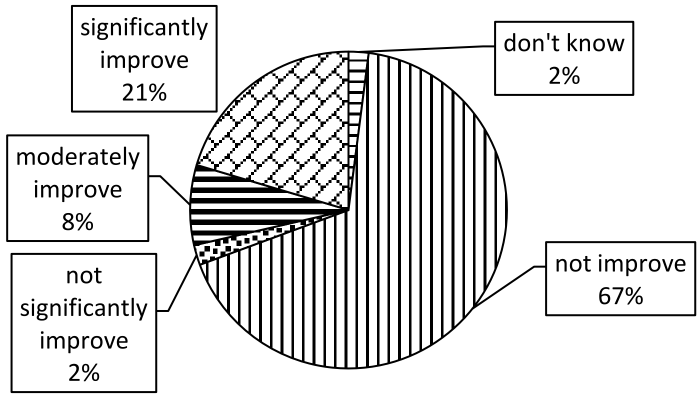
(a) survey II



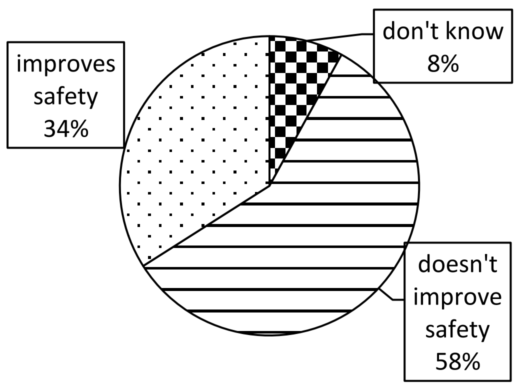
(b) survey I

Figure 126
Opinion on safety benefits of the DSL policy from surveys I and II

(Q7) Opinion on the safety benefits of the truck lane restriction: Similar to the results obtained in Q6, Figure 127 shows that 67 percent of the respondents thought the truck lane restriction had no effect on freeway safety. Among the 31 percent who thought it did have a positive impact, 21 percent felt the benefit was high, and 8 percent thought the benefit was moderate. The results were similar to those from the first survey, indicating that most of the respondents felt the truck lane restriction did not benefit freeway safety or that the safety benefits were not as significant.



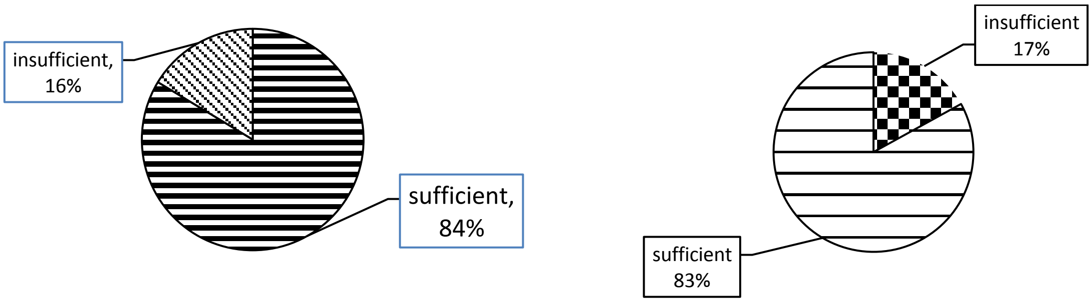
(a) survey II



(b) survey I

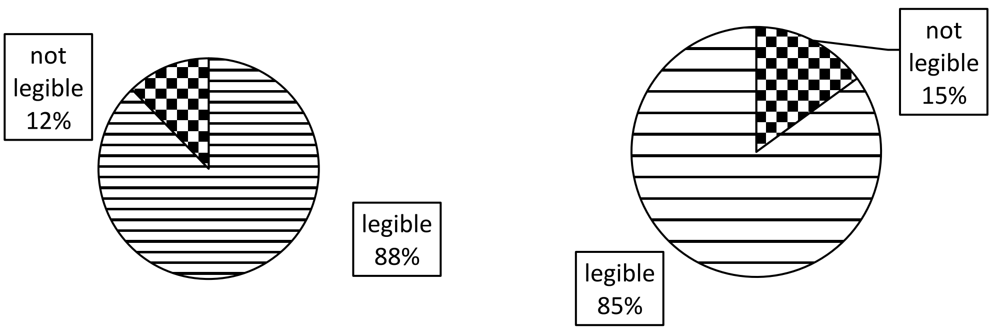
Figure 127
Opinion on safety benefits of the DSL policy from surveys I and II

PART 5: Warning and Enforcement
(Q8) Advance warning sufficiency: 84 percent of respondents reported that the advanced warning of speed and truck lane restriction was adequate as shown in Figure 128. For (Q9), similarly, 88 percent felt that the warning signs were adequately legible, as shown in Figure 129. The results were also consistent with those from the first survey, suggesting that advance warning signs were sufficient.



(a) survey II (b) survey I

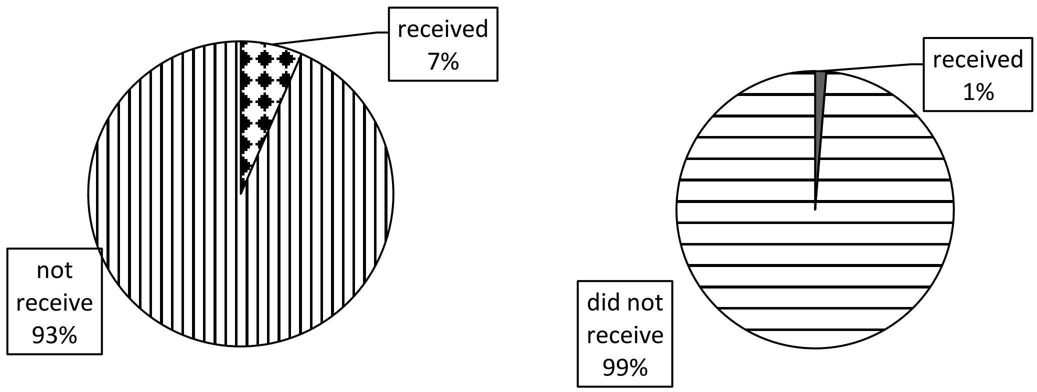
Figure 128
Sufficiency of warning about speed limit and lane restriction from surveys I and II



(a) survey II (b) survey I

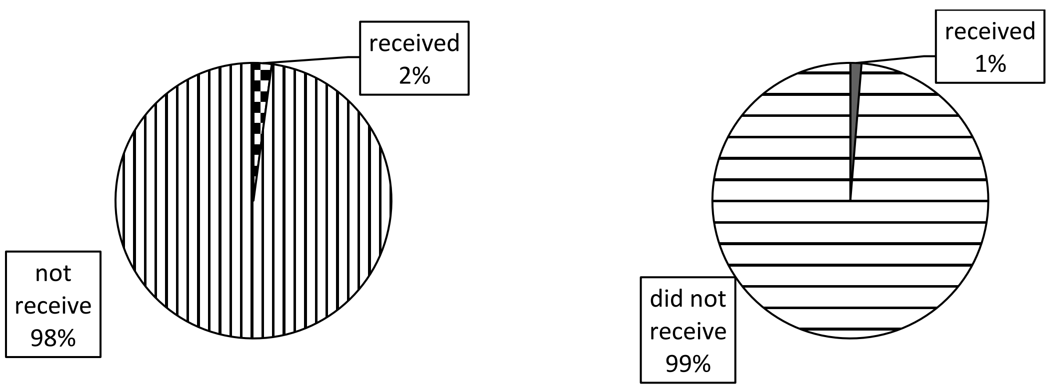
Figure 129
Legibility of roadway signs from surveys I and II

(Q10) Violations: Figure 130 shows the percentage of respondents who received a speeding ticket. The results show that 7 percent reported receiving a speeding citation since the policy change in September 2003. For those who received citations, the number of citations reported was less than 5 percent. Similarly, only 2 percent reported receiving a lane change citation once since the policy change in September 2003 as shown in Figure 131. A slightly higher percentage of respondents receiving citations were reported in the second survey.



(a) survey II (b) survey I

Figure 130
Speeding citation from surveys I and II



(a) survey II (b) survey I

Figure 131
Lane changing citation from surveys I and II

(Q12) Reason for Changing Lanes: As shown in Figure 132, the two most common reasons for making lane changing maneuvers are to pass slow vehicles and to avoid broken down, emergency, or police vehicles on the shoulder. The percentages of the total respondents that stated these reasons are 47 percent and 37 percent, respectively. Compared to the first survey, fewer reasons for lane changing were reported in the second survey, which may be due to the smaller sample size of the new survey (49 responses). However, passing slow vehicles and avoiding vehicles on the shoulder were the top two reasons for lane changing for drivers of all experience levels in both survey results.

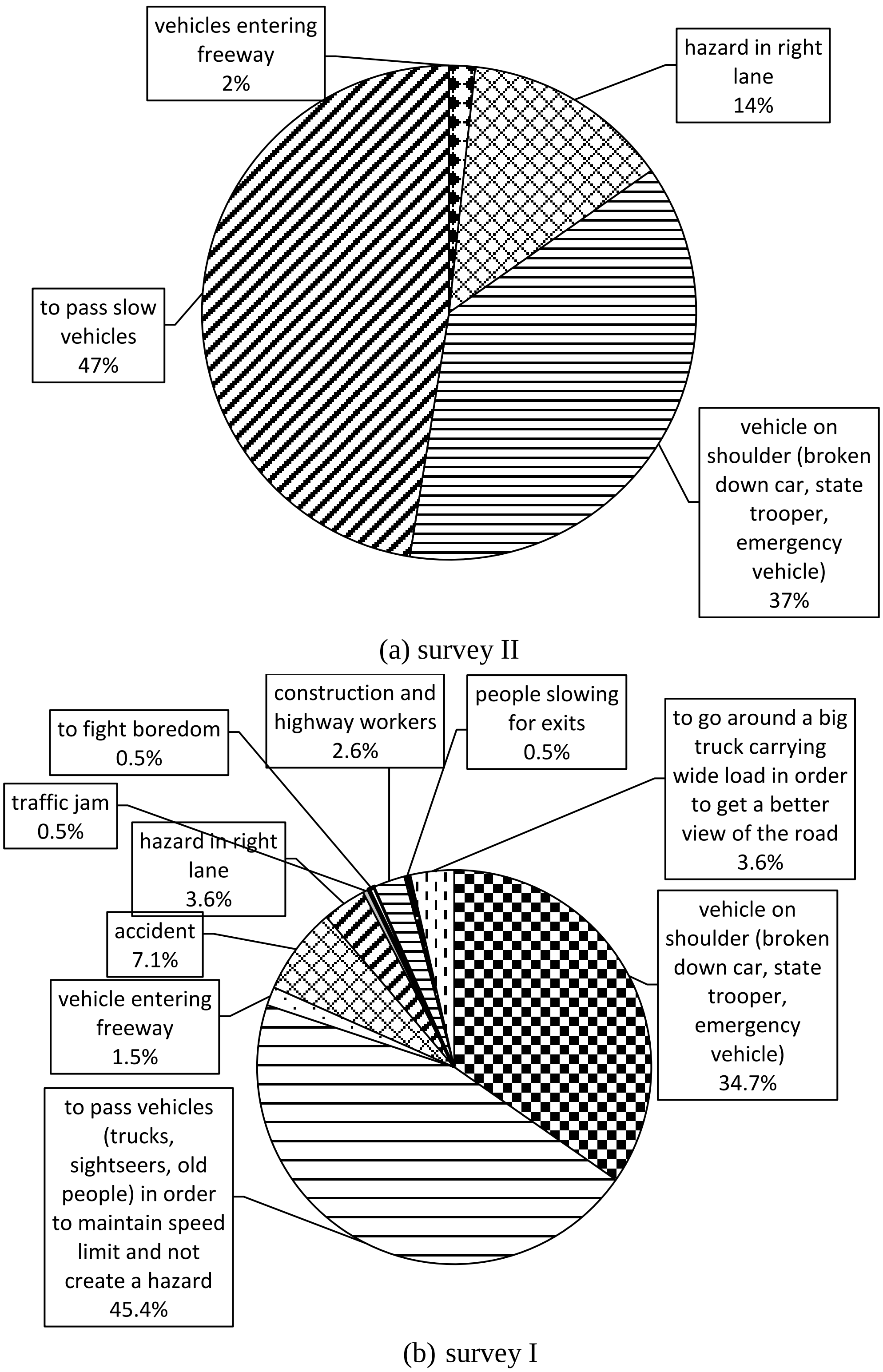


Figure 132
Drivers' reasons for lane changing from surveys I and II

(Q13 a&b) Keeping speed limits: Table 64 presents the frequency of those favoring to keep the speed limits for trucks and cars on a likert scale from 1 to 5. The expected scale value for the opinion on maintaining the 55 mph speed limit for trucks is 2.08, which indicates a moderate disagreement on the speed limit restriction. The corresponding number for car speed limits was 3.10, which shows that the respondent truckers are somewhat neutral about the speed limit for passenger cars. The first survey results show that 85 percent did not favor maintaining the current 55 mph truck and 60 mph car speed limits. Combining the results of the two surveys, it can be noted that the large percentage of dissatisfaction with the current DSL restriction is mainly due to the disagreement on lowering the truck speed limit.

Table 64
Opinion on the current speed limits from survey II

Keep truck speed limit			Keep car speed limit		
Bin	Frequency	Bin*Frequency	Bin	Frequency	Bin*Frequency
1	25	25	1	11	11
2	11	22	2	8	16
3	2	6	3	4	12
4	3	12	4	15	60
5	7	35	5	10	50
sum	48	100	sum	48	149
expected value		2.08/5.00	expected value		3.10/5.00

(Q13c) Truck lane restriction: the responses towards the current truck lane restriction policy are summarized in Table 65. The expected value of 2.21 indicates a general negative attitude to the lane restriction of trucks. Correspondingly, the first survey results for this question show that only 21 percent of the respondents favored maintaining the current truck lane restriction. The two surveys evidently yield similar results that the respondent truckers do not favor policies that restrict their freedom to choose the travel lane on the study segment.

Table 65
Opinion on the current truck lane restriction from survey II

Keep truck lane restriction		
Bin	Frequency	Bin*Frequency
1	22	22
2	11	22
3	4	12
4	5	20
5	6	30
sum	48	106
expected value		2.21/5.00

(Q13 d&e) Trucks and passenger cars speed limits: Totally, seven different combinations of the favored speed limits for trucks and passenger cars were reported in the second survey, among which four combinations prefer to same speed limits for both types of vehicles. Figure 133 illustrates the percentage for each speed limit combination. It is noted that the majority of the respondents (92 percent) favor the same speed limit for both trucks and cars. About 51 percent of them favor 60 mph for both trucks and cars, followed by 28 percent favoring 65 mph for both types of vehicles. In addition, the results show that only 6 percent of the respondents favored truck speed limit equal or lower the current one, while more (54 percent) suggested a limit equal to or lower than the current car speed limit. This is consistent with the first survey results, where only 33 percent of the respondents favored the lower truck speed limit, while 55 percent favored the current car speed limit, as shown in Figure 134. These findings suggest that the respondents are not satisfied with the current truck speed limit.

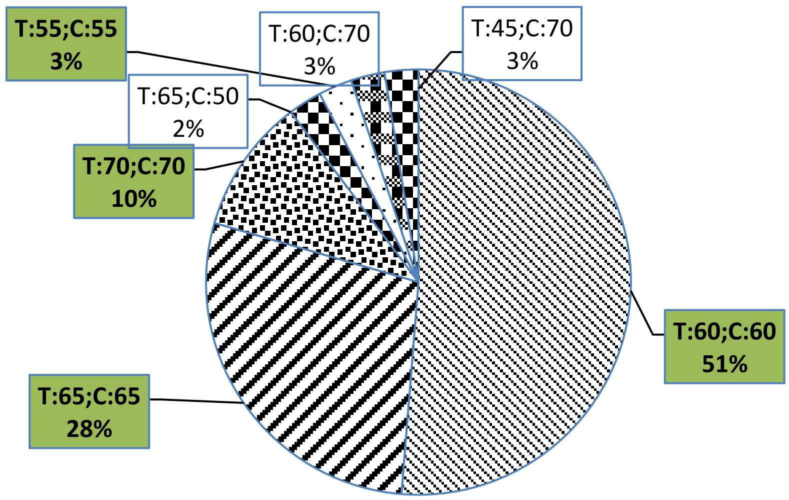


Figure 133
Favored speed limits for trucks and passenger cars from survey II

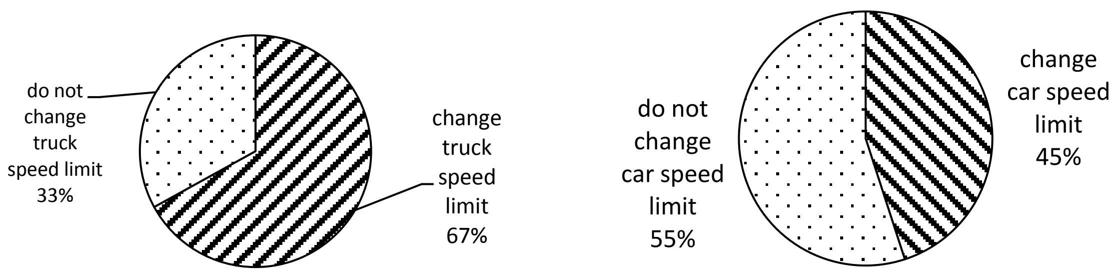
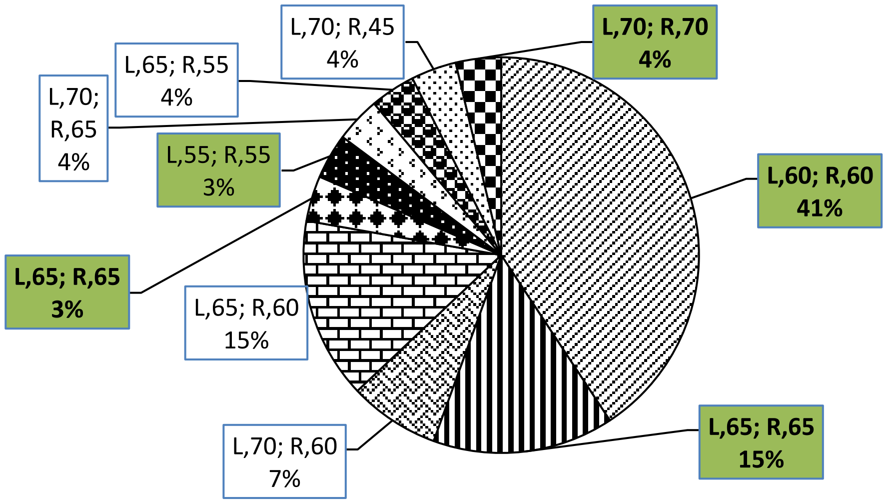
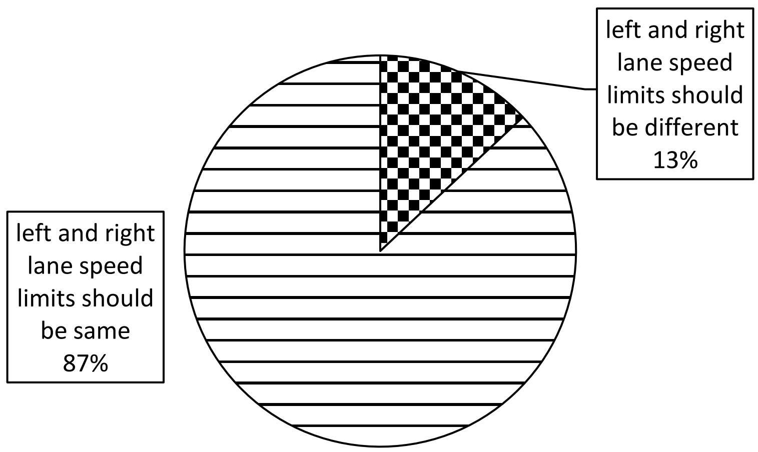


Figure 134
Truck and passenger car speed limits from survey I

(Q13f) Lane-specific speed limits: only about half of the respondents (27 out of 49) specified their favored speed limits for both left and right lanes, and scattered values of speed-limit combinations categories were reported in the second survey. As shown in Figure 135, five of ten categories (66 percent) favor the same speed limits for both left and right lanes. Favoring a speed limit of 60 mph for both lanes accounts for the largest percentage (41 percent) of the respondents. This is similar to the results obtained from the first survey, where 87 percent of the respondents did not favor differential speed limit for the right and left lanes. In survey II, those favoring right and left lane speed limits preferred the option of 65 mph for the left lane and 60 mph for the right lane on the elevated study segment. This is also consistent with the findings of the first survey.



(a) survey II



(b) survey I

Figure 135
Lane-specific speed limit from surveys I and II

(Q13g) Peak-hour speed limits: Table 66 presents the summarized results of opinions on reducing the speed limits during peak hours. The expected value of 2.09 indicates that the respondents did not favor varying speed limits during the peak and non-peak periods. It is consistent with the results from the first survey, where 89 percent of the respondents disagreed on reducing speed limit during peak hours.

Table 66
Opinion on reducing the speed limit during peak hour

Bin	Frequency	Bin*Frequency
1	16	16
2	18	36
3	5	15
4	6	24
5	1	5
sum	46	96
expected value		2.09/5.00

(Q13h&i) Incident detection and warning: the expected value calculated from the responses on incident detection and warning is 4.41 as shown in Table 67. This indicates that the respondents strongly favored the incident detection and warning mechanisms, which is consistent with results from the first survey, wherein 54 percent of the respondents favored the same mechanisms. However, there is a considerable discrepancy between the two surveys on the speed detection mechanism. The expected value for speed detection obtained from the second survey is 3.54, which shows a general positive attitude towards the speed detection mechanism. On the contrary, the first survey shows that 75 percent of the respondents did not favor a speed detection that informed drivers of their current speed. The discrepancy may have resulted from the different sample size of the two surveys.

Table 67
Opinion on incident and speed detection

Incident detection and warning			Speed detection		
Bin	*Frequency*	Bin*Frequency	*Bin*	*Frequency*	Bin*Frequency
1	2	2	1	4	4
2	1	2	2	6	12
3	1	3	3	8	24
4	14	56	4	17	68
5	28	140	5	11	55
sum	46	203	sum	46	163
expected value		4.41	expected value		3.54

(Q13j) Fines: Table 68 summarizes the responses on increasing fines for speed and lane violations. As expected, the findings suggest that the respondents did not favor raising traffic violation fines, as indicated by the expected value of 3. The results are similar to that of the first survey, wherein 89 percent of the respondents were not in favor of increasing the speed and lane violation fines.

Table 68
Opinion on increasing fines

Bin	Frequency	Bin*Frequency
1	15	15
2	15	30
3	10	30
4	3	12
5	2	10
sum	45	97
expected value		2.16

(Q13 k, l, &m) Lane restriction: As shown in Table 69, the respondents strongly disfavored any lane restrictions for both cars and trucks. It is consistent with the results from the first survey, wherein the percentages of respondents not in favor of the left lane restriction for trucks and left/right lane restriction for cars are 89 percent, 92 percent, and 96 percent, respectively.

Table 69
Opinion on lane restrictions

left lane restriction for trucks			left lane restriction for cars			right lane restriction for cars		
Bin	*Frequency*		Bin	Frequency		*Bin*	*Frequency*	
1	23	23	1	20	20	1	20	20
2	19	38	2	22	44	2	22	44
3	3	9	3	1	3	3	1	3
4	0	0	4	1	4	4	1	4
5	0	0	5	2	10	5	2	10
sum	45	70	sum	46	81	sum	46	81
expected value		1.56/5.00	expected value		1.76/5.00	expected value		1.76/5.00

(Q13 n&o) Lane changing: The results shown in Table 70 indicate that the respondents are strongly against the restriction on lane changing for both trucks and cars. Similar findings were obtained from the first survey, where over 90 percent of the respondents did not favor restricting trucks and cars to the lane they were in at the beginning of the section.

Table 70

Opinion on lane changing restrictions for trucks and cars

Restrict lane changing of trucks			Restrict lane changing of cars		
Bin	*Frequency*	Bin*Frequency	*Bin*	*Frequency*	Bin*Frequency
1	24	24	1	23	23
2	18	36	2	20	40
3	2	6	3	2	6
4	1	4	4	1	4
5	0	0	5	0	0
sum	45	70	sum	46	73
expected value		1.56	expected value		1.59

(Q13p) No restrictions: The results shown in Table 71 indicate that the respondents prefer no restriction to trucks in terms of lane use or lane changing. It is consistent with the results from the first survey, which shows 58 percent of respondents in favor of no restrictions to trucks.

Table 71

Opinion on not implying any restrictions on trucks

No restrictions on trucks		
Bin	Frequency	Bin*Frequency
1	6	6
2	9	18
3	4	12
4	8	32
5	19	95
sum	46	163
expected value		3.54

(Q13q) Barrier separation: Table 72 indicates that the respondents strongly disagreed on using physical barriers to separate the left lane from the right lane. It is consistent with the results of first survey, which showed 96 percent of respondents not in favor of the barrier separation.

Table 72
Opinion on barrier separation of left and right lanes

separate left lane from right lane		
Bin	Frequency	Bin*Frequency
1	34	34
2	10	20
3	0	0
4	1	4
5	1	5
sum	46	63
expected value		1.37

(Q13r) Lighting improvements: As shown in Table 73, the respondents strongly favored making lighting improvement on the study segment. The first survey showed that the respondents were split (51 in favor-49 not in favor) on the issue of making lighting improvements on the section.

Table 73
Opinion on lighting improvement

Bin	Frequency	Bin*Frequency
1	1	1
2	2	4
3	10	30
4	16	64
5	16	80
sum	45	179
expected value		3.98/5.00

(Q13s) Law enforcement improvement: surprisingly, the results from the new survey show that the respondents were in favor of enhancing the current law enforcement, while in the original survey 73 percent of the respondents did not favor increasing the number of the law enforcement patrols. These findings suggest room for law enforcement improvement.

Table 74
Opinion on increasing law enforcement patrols

Bin	Frequency	Bin * Frequency
1	5	5
2	2	4
3	22	66
4	9	36
5	8	40
sum	46	151
expected value		3.28/5.00

(Q13t) Other improvement strategies: Only a total of 23 truckers responded to this question. The responses were grouped into five categories as shown in Figure 136. Compared to the first survey, the respondents in the second survey were more concerned with the speed and lane restriction policies, and several respondents suggested safety training.

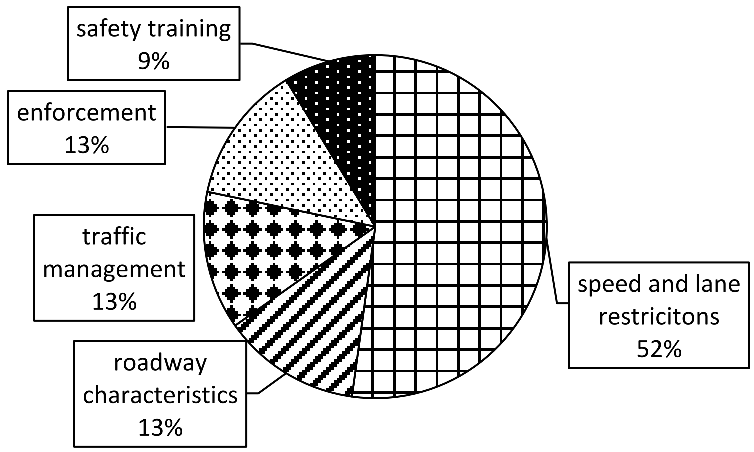
Speed and lane restrictions: Six respondents preferred uniform speed limits for trucks and cars, and two favored no truck lane restriction. One respondent suggested varying speed limits based on the weather; another respondent suggested setting minimal speed on the left lane. One respondent thought the range of 65-70 mph is a rational range for speed limits, and one respondent suggested reducing only the speed limit between 1 am and 10 am, since this is the "fog" hour at the study section.

Roadway characteristics: One respondent suggested widening the structure to allow trucks in the right two lanes, one respondent even suggested building a separate roadway for 18 wheelers and cars, one respondent suggested adding a high occupancy lane between the two spans and running it one way during peak hours or adding another lane to both sides, and one respondent wrote that cut grooves could improve safety.

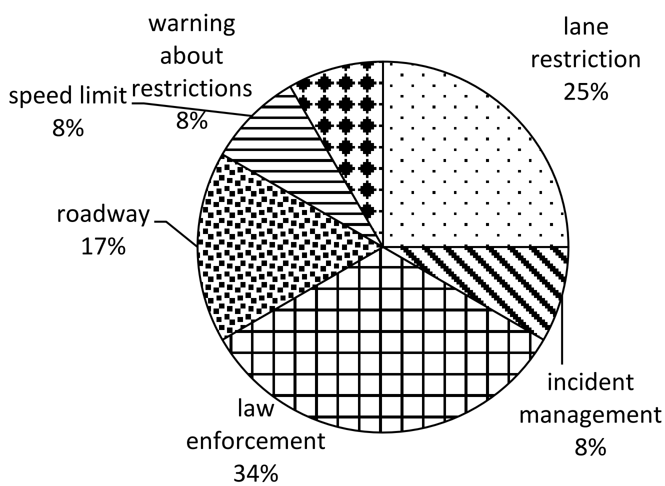
Traffic management: One respondent suggested implementing ITS devices to the fullest extent, one respondent pointed out to the necessity of placing lots of cameras and flashing yellow lights along entire bridge, especially when cameras detect an accident, and one respondent suggested that cars, trucks, and police are not stopped on the shoulder unless absolutely necessary.

Enforcement: One respondent suggested penalizing non-professional drivers, one respondent asked for more police coverage on the bridge, one respondent suggested more enforcement on cars, and one respondent thought that doubling the fine is a good strategy.

Safety training: Two respondents stressed the importance of safety training; one suggested at least 3 weeks of training in a lifetime for everyone.



(a) survey II



(b) survey I

Figure 136
Other improvement strategy areas

(Q14) Benefits of proposed improvement strategies: a total of 22 truckers responded to this question. Only two responses implied that the proposed strategies would reduce accidents. Other respondents stated what they think may improve safety. The responses were grouped into the following five groups:

Speed limits and lane restriction: Six respondents thought that uniform speed limits are a better option than differential speed limits as far as safety is concerned. One respondent warned of the "wall effect" caused by keeping trucks in the right lane.

Distraction/confliction: Four respondents believed the main reason for accidents are distractions and conflicts. One response suggested using ITS device to minimize distraction.

Incident warning: Two respondents stated that notification of accidents ahead of time should help prevent some secondary accidents.

Enforcement: Three respondents thought more enforcement would improve safety.

Safety training: Two respondents believe better driver training would help everyone drive more safely.

(Q15) Comments: The truck drivers showed their strong disagreement on DSL and truck lane restriction. Six respondents pointed out that split speed limits are dangerous. One respondent wrote that at least two states have passed legislation this year to end the split of speed limits because it is very dangerous. In addition, three respondents believed lane restrictions would cause hazard for truck drivers.

Three respondents thought passenger cars caused more accidents by speeding and careless driving and suggested applying more enforcement on cars. One respondent thought the fines for tickets should be the same for all vehicles and speed limits.

One respondent suggested using smart highway devices to create a safer, smoother flow of integrated (commercial and personal) traffic.

Survey Conclusions

- The study conducted two surveys to poll the opinions of the trucking industry on the restriction policies along the study segment. The first survey was a mail-in survey sent to nearly 500 companies. A total of 159 responses were received back and the results were analyzed. The second survey was conducted online using the DOTD Web site. A total of 49 responses were collected over a period of two months and the results were also analyzed and compared to those of the first survey.
- Overall, both surveys showed consistent results on all questions.

- The majority of the survey respondents are experienced semi-trailer drivers who are aware of the truck lane restriction and differential speed limit practice over the Atchafalaya Swamp Freeway.
- The general view about the continuation of the current lane and speed policies is negative. Reduced road view, long queue of trucks in the right lane, difficulty merging to the freeway, and reduction in traffic safety are the reported reasons for the opposition with the implementation of the lane restriction. Respondents also reported that the low truck speed limit reduces driver alertness and causes truck drivers to fall asleep. Respondents were clearly in favor of a raised truck speed limit that is same as the car speed limit. A 60 mph uniform speed limit was the popular choice due to its benefits to traffic safety and efficiency.
- The positive opinion on the safety benefits of the current policies is most popular among the group of drivers with 5 years or less experience and the ones who drive straight trucks. These respondents also supported the simultaneous application of truck lane restriction and differential speed limit.
- While safety was reported to be the main reason that urges drivers to change lanes, allowing truck drivers to use the left lane only to pass slower trucks is a common strategy that was proposed.
- The majority of the respondents think the signs warning about the speed and lane policies over the stretch are legible and understandable, but they also welcome the implementation of incident detection systems and improvement in lighting due to the safety benefits they will bring.
- Raising the violation fines, implementing a speed monitoring system, and placing a barrier between the lanes are not favorably looked upon. Alternative ideas to attain more effective law enforcement and improved roadway physical characteristics were presented by some respondents in the write-in sections.
- Survey responses strongly suggest that the responders have a clear preference to have few restrictions as possible, in general. This is true in terms of speeds and lane use and for the two vehicle types considered, cars and trucks. It is also particularly true in terms of rules that tend to demonstrate a preference for car traffic at the expense of trucks.
- In addition, they also showed a clear preference for uniform (rather than varying) rules for different vehicles and time. It was especially noteworthy between cars and trucks. The respondents expressed a consistent preference for one set of rules for all vehicles. This idea was also consistent when asked to differentiate between lanes and between peak and non-peak times.
- The write-in responses also suggest that the survey respondents are very interested in any restriction or non-restriction policies that promote smoother flow and in general good operational conditions vs. ameliorating safety.

- Several chi-square tests of independence were conducted and the following facts were found:
  1. There is no significant dependency between drivers' familiarity with the area (travelled more than 100 times over the study section) and their stated preference to remove the 55 mph truck speed limit and truck lane restriction.
  2. There is significant statistical evidence that correlates that drivers travelled more frequently over the viaduct (100 times or more) with their stated preference to remove 55/60 mph differential speed limit.
  3. There is significant statistical evidence that drivers favoring 55/60 mph differential speed limit relate this restriction to its potential safety benefits.
  4. Similarly, significant statistical evidence shows that drivers favoring truck lane restriction also believe in its potential safety benefit.
  5. Significant statistical evidence shows that lane restriction's impact on safety is a driving factor in supporting the continuation of the 55/60 mph speed limit practice.
  6. Significant statistical evidence shows that heavy truck (i.e.,tractor semitrailer) drivers are inclined to believe that 55/60 mph differential speed limit has a negative impact on safety.
  7. There is no significant dependency between respondents' driving experience and their opinion about the impact of truck lane restriction on traffic safety.
  8. There is significant dependency between respondents' driving experience and their opinion about the impact of 55/60 mph differential speed limit on traffic safety. In other words, driving experience influences drivers' opinion on the safety impact of the differential speed limit application (e.g., drivers with moderate experience, 11 to 15 years, tend to think that differential speed limit reduces traffic safety).
- Additional statistical analysis (i.e., canonical correlation) revealed results consistent with the findings of the previous chi-square tests. Basically, from a behavior's stand point it was found that the more experienced a truck driver is, the more aware he is of the restrictions on trucks and less likely to receive citation for violation of the restrictions. Also, it was found that the primary reason for changing lanes is to avoid accidents or hazard in the right lane. The respondents supporting the existing 55/60 mph differential speed limit and lane restriction believe that these practices help improve the traffic safety and these respondents do not want a change in the speed limit for trucks. However, the same group of respondents thinks that there is a need for improving the existing DSL and truck lane restriction warning signs.
- The correlation analysis shows that truck drivers with more experience do not agree with the existing restrictions. In addition, it was found that the lane change behavior has a significant effect on the opinion of the truck restrictions. For example, the drivers who change lanes mainly for passing the slow vehicles are not in favor of keeping the 55 mph speed limit for trucks, and they prefer no restriction on trucks. In contrast, the drivers who change lanes to

avoid accident or hazard in the right lane believe that right lane restriction for trucks can improve safety, and they support the continuation of the 55 mph speed limit for trucks.

Safety Analysis

Overview of Freeway Speed Limit

- On November 28, 1995, National Maximum Speed Limit (NMSL) was repealed
- DOTD raised the speed limit to 70 mph June 1997
- Speed limit changed from 70 mph to 60 mph in August 1998 after a series of crashes occurred resulting 4 fatalities and 32 injuries,
- In September 2003, DOTD installed a differential speed limit on Atchafalaya I-10 segment restricting trucks on right lane with 55 mph speed limit. The speed limit for cars stays at 60 mph.

To our knowledge, many states have implemented DSL on the selected highways. However, the results on highway safety have been mixed. Some studies reported a decrease in crashes while other studies concluded no difference or worse an increase in crashes (Kobelo and Moses, 2007, Neeley and Richardson, 2004, Hall and Dickinson, 1974, Garber et al, 2005, Garber and Gadiraju, 1992, Novotny, 2005, Pant et al, 1992, Srinivasan et al, 2005, and Johnson and Pawar, 2005). Key information missing from some of those studies are the lane restrictions. DSL would not work without lane restrictions since differential operating speed creates higher crash risk for traffic flow (Lamn et al, 1999). Vehicles operating in the same lane with different speed limits would create a big gap in operating speed. The larger the gap in operating speed, the higher crash risk.

To answer the basic questions “Do the differential speed limit and truck lane restriction affect highway safety? And if, yes, how much?” the following analysis was performed:

1. Descriptive crash statistics
2. Statistical analysis

For the descriptive crash analysis, 12 years of data were used (1995-2006) and for the statistical testing, only six years of data was used with three years before the implementation of differential speed limit (2000, 2001, and 2002) and three years after (2004, 2005, and 2006).

Descriptive Crash Statistics

To reveal the nature and magnitude of the safety problem, the descriptive crash analysis was performed, which illustrates basic characteristics of crashes on Atchafalaya I-10.

Temporal Distribution

The following charts display the distribution of total crashes and fatal crashes by year, month of the year, and hours of the day. Since the number of crashes is closely related to traffic volume and Average Annual Daily Traffic (AADT) varies year by rear, the crash rate, in term of crashes per million VMT, is also calculated.

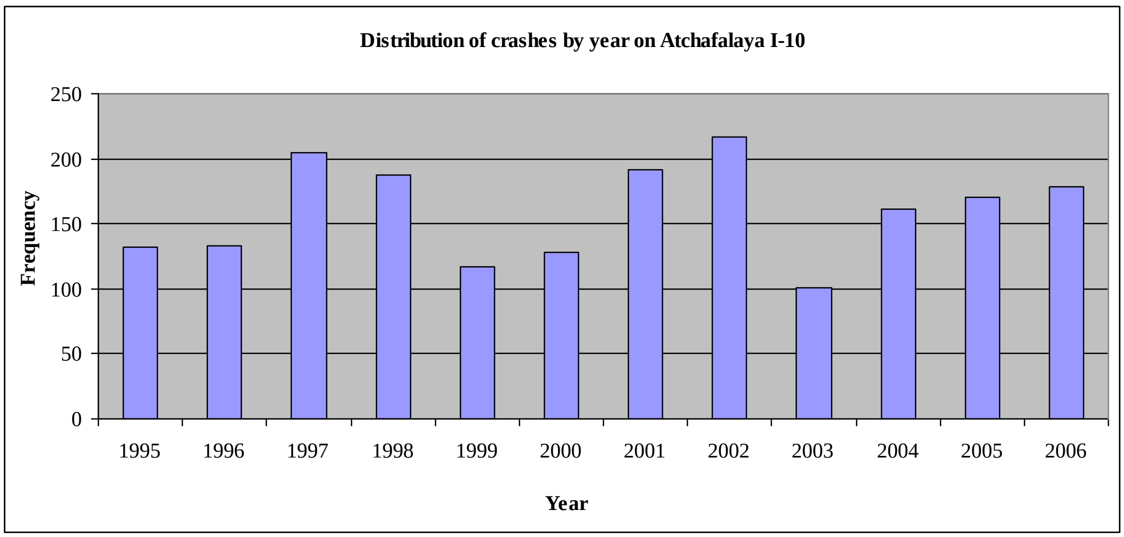


Figure 137
Distribution of annual crashes

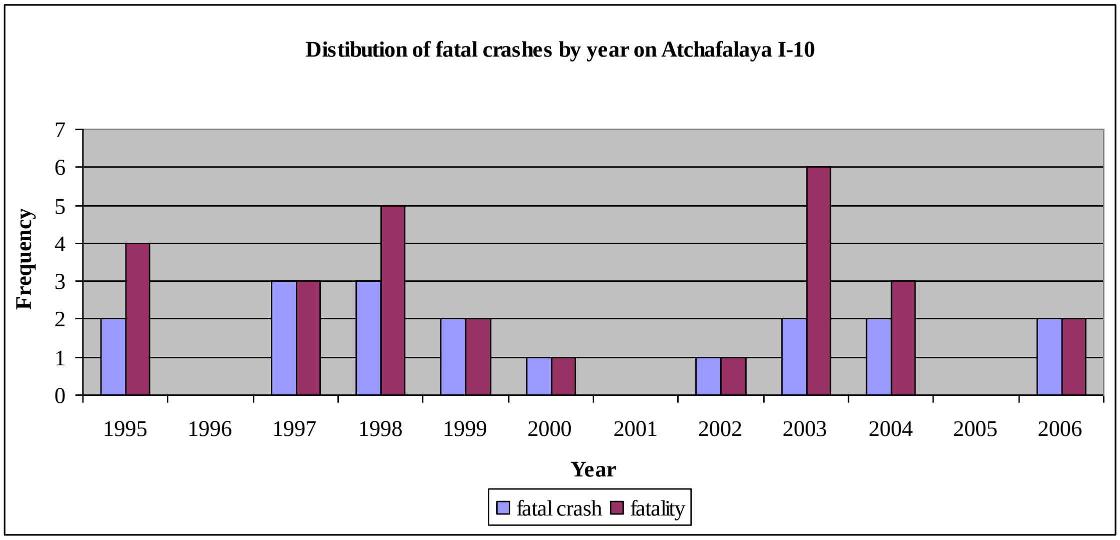


Figure 138
Distribution of annual fatal crashes and fatalities

Apparently, 2002 and 1997 are the worst years in terms of crash frequency. The distribution of annual fatalities differs from the total crash frequency distribution. More fatalities occurred in 1998 and 2003, the years the speed limits were modified.

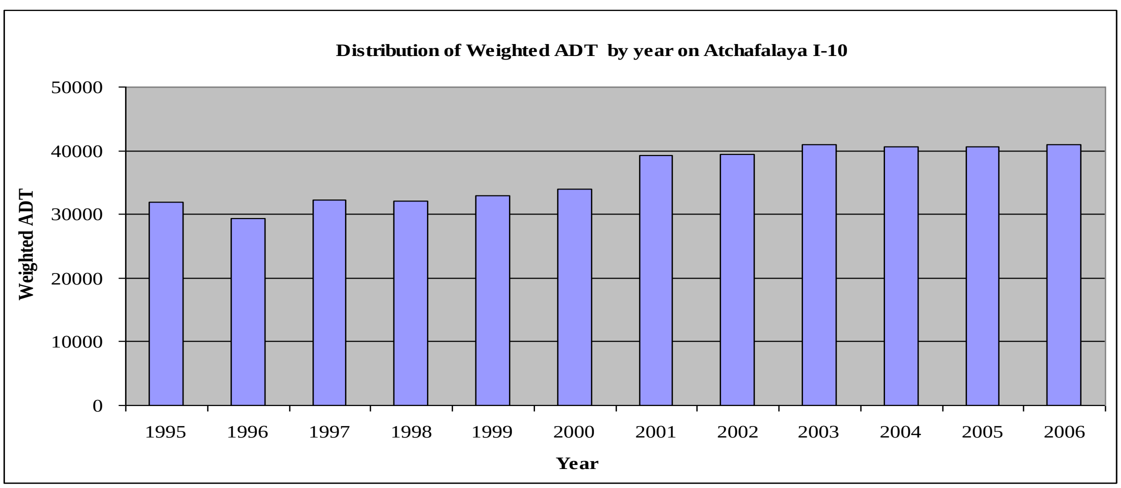


Figure 139
Distribution of AADT

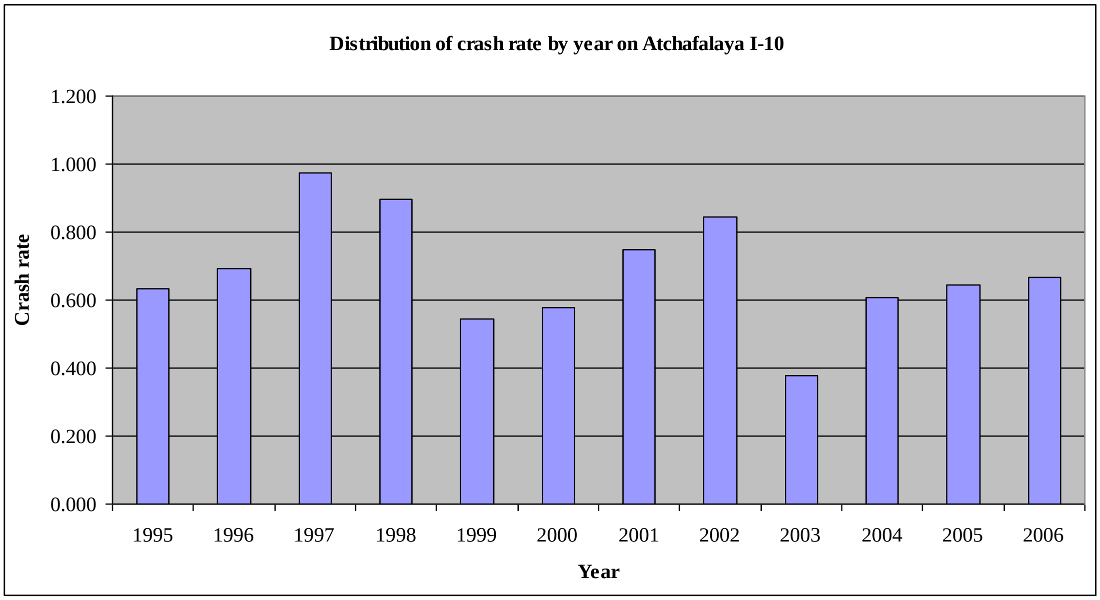


Figure 140
Distribution of annual crash rate

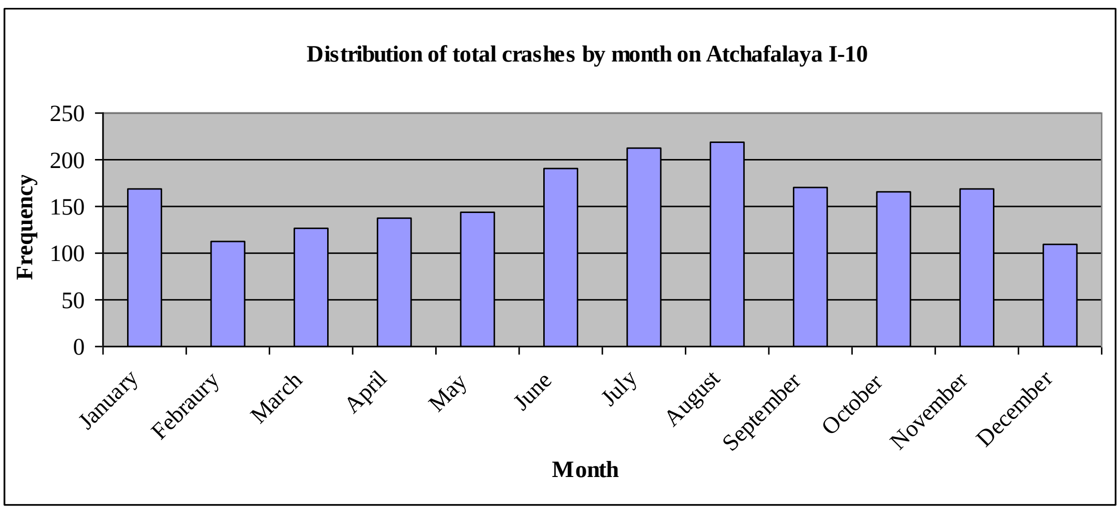


Figure 141
Distribution of crashes by month of the year

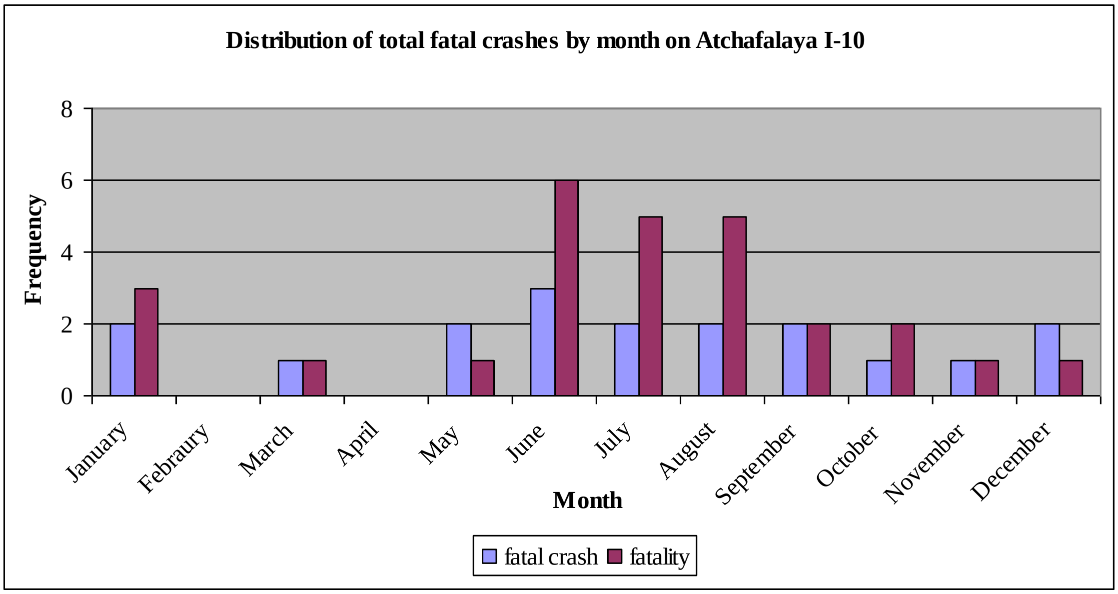


Figure 142
Distribution of fatal crashes by month of the year

From Figure 141 and Figure 142, it seems summer time experienced more crashes than other times. However, it is interesting to note that there is a close correlation between the monthly number of citations issued by enforcement and monthly crash frequency as shown in Figure 143.

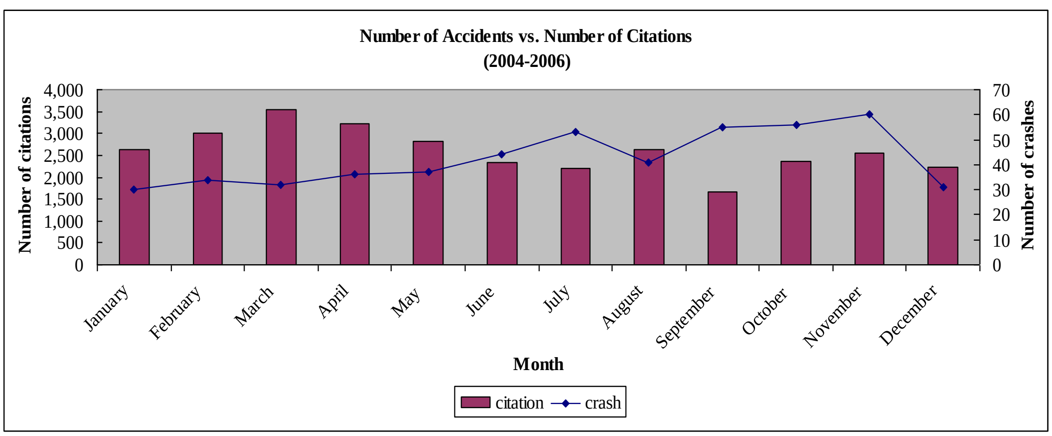


Figure 143
Distribution of number of citations and number of crashes by month (based on three years of crash and citation data)

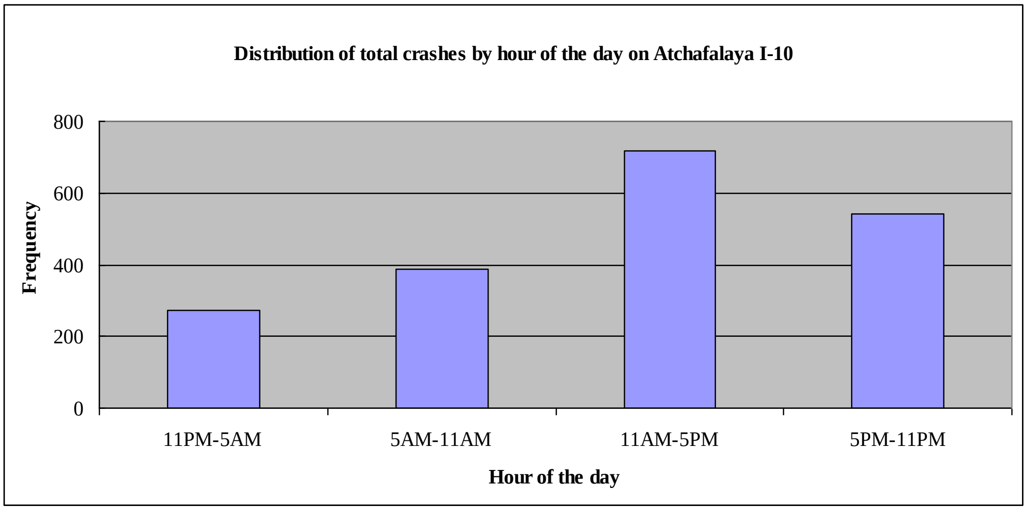


Figure 144
Distribution of crashes by period of the day

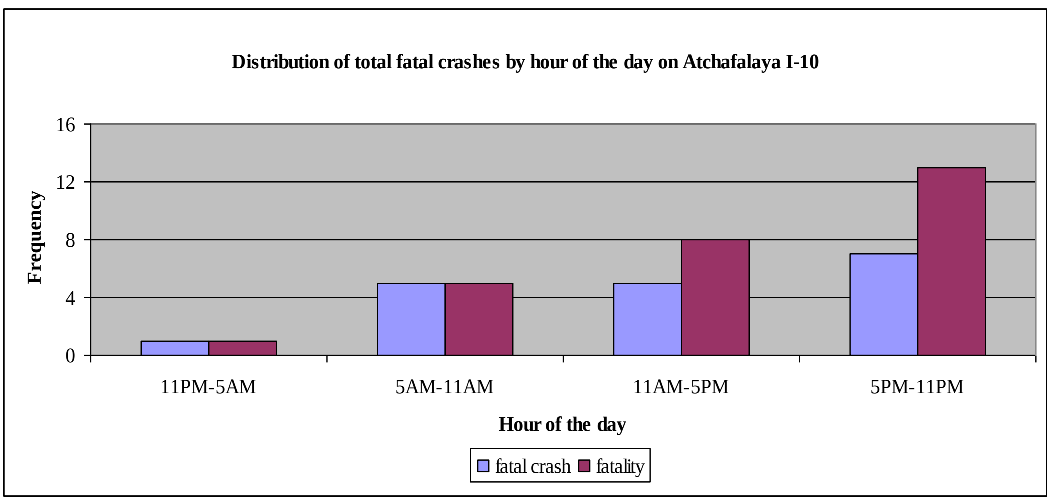


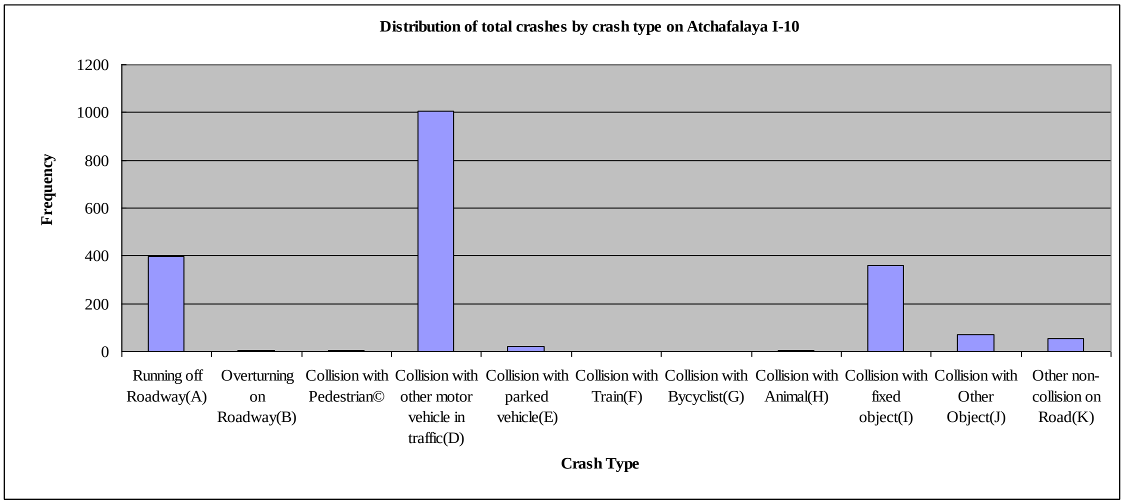
Figure 145
Distribution of fatal crashes by period of the day

In summary, the following observations are drawn:

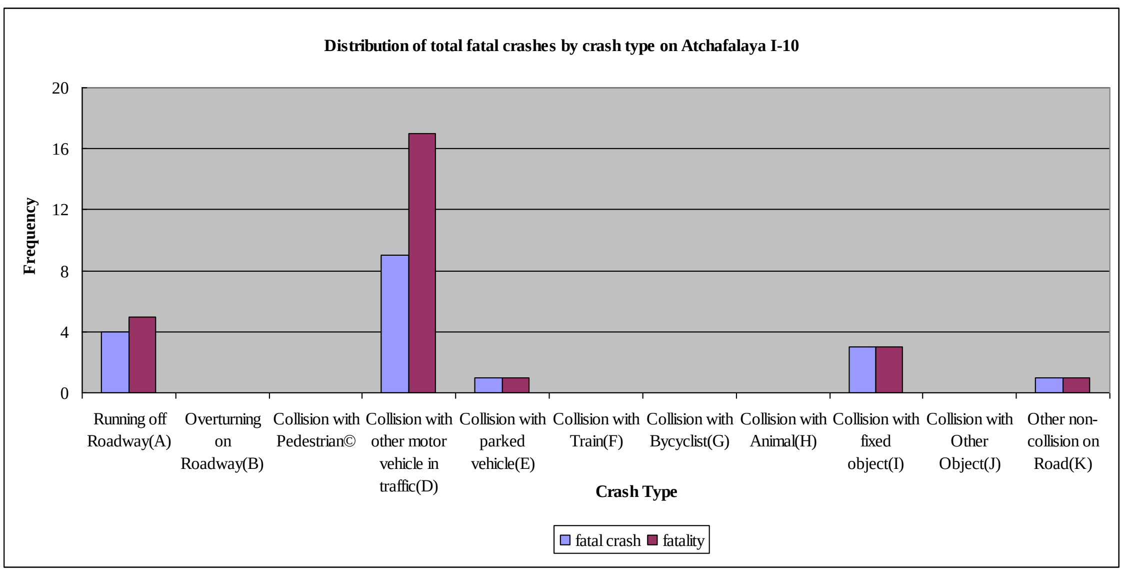
- Annual crash frequency varies, and 1997 and 2002 seems to be the worst years
- 1998 and 2003 are the worst years in fatal crashes
- Crash risk is higher during summer
- More crashes occurred during a 11 a.m.-5 p.m. time period and more fatal crashes happened during a 5 p.m. to 11 p.m. time period.

Crash Characteristics

The distributions of type of crash, type of collision, type of crashed vehicles, number of vehicles, and crash severity are displayed in this section.

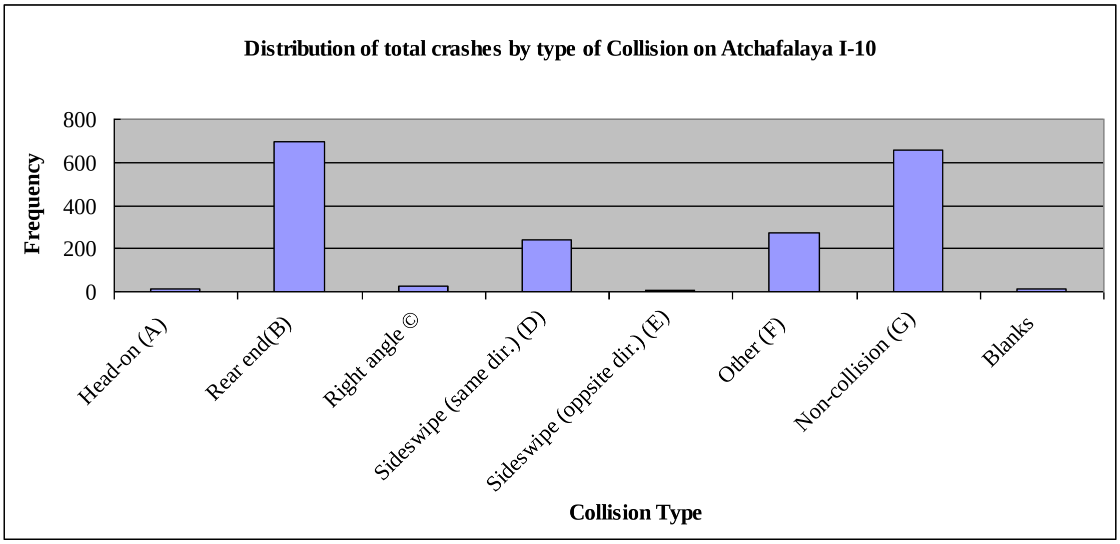


(a) Total crashes

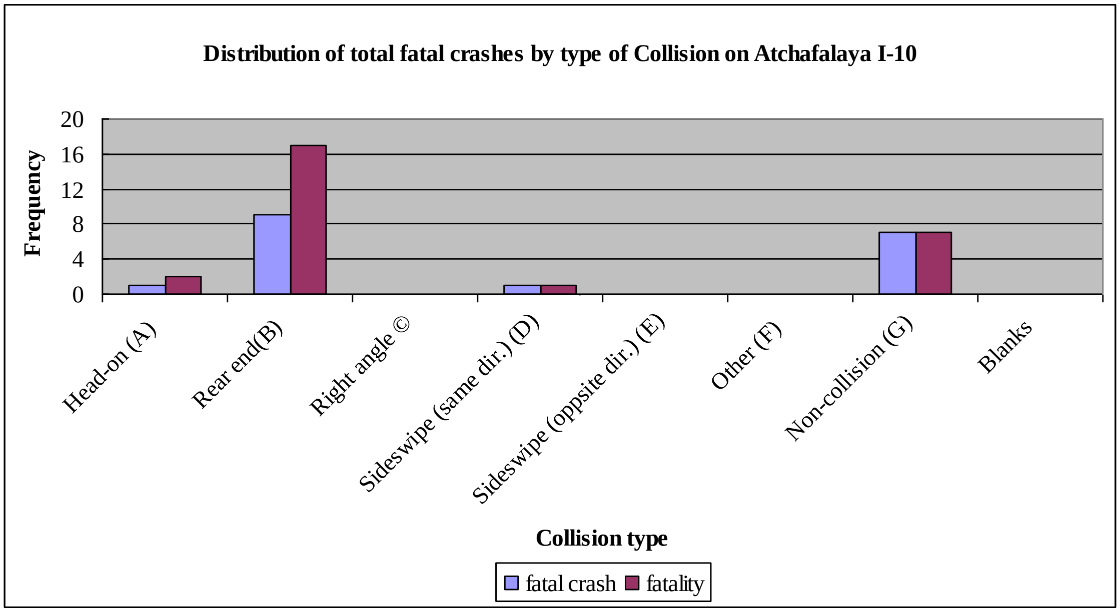


(b) Fatal crashes

Figure 146
Distribution of crash type

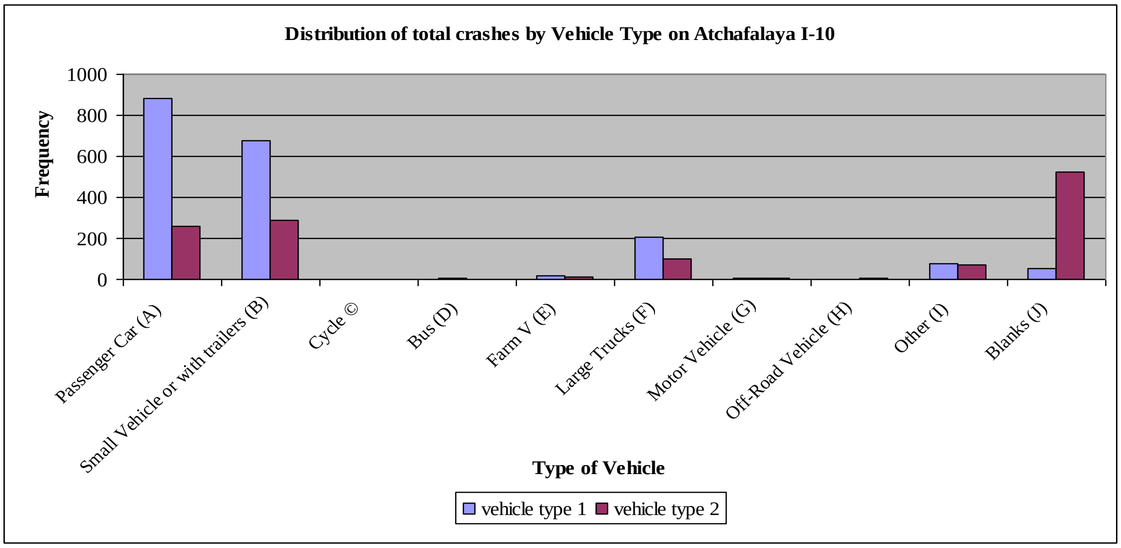


(a) Total Crashes

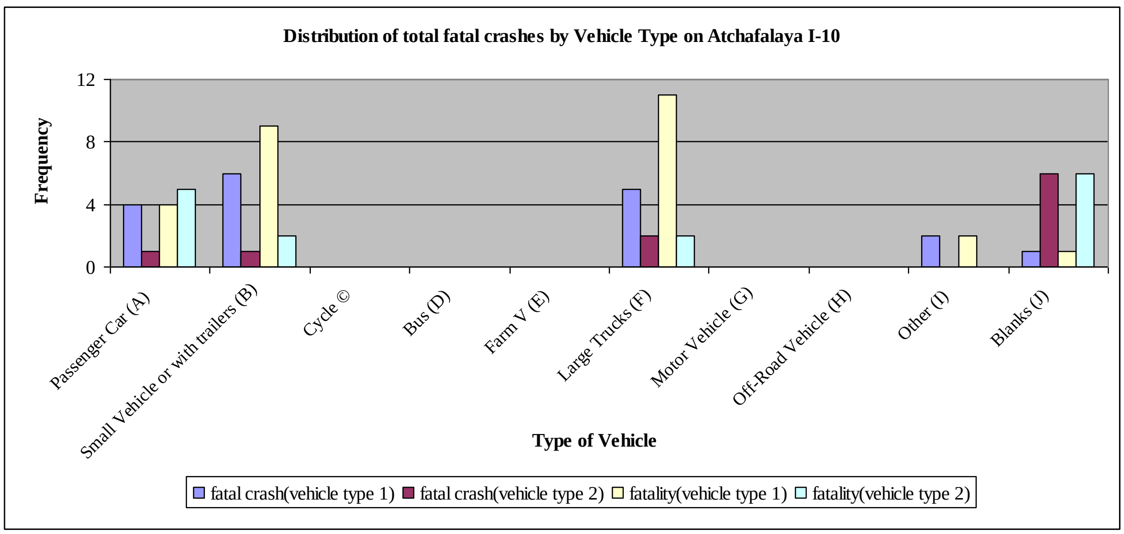


(b) Fatal Crashes

Figure 147
Distribution of collision type



(a)Total Crashes



(b) Fatal Crashes

Figure 148

Distribution of vehicle type

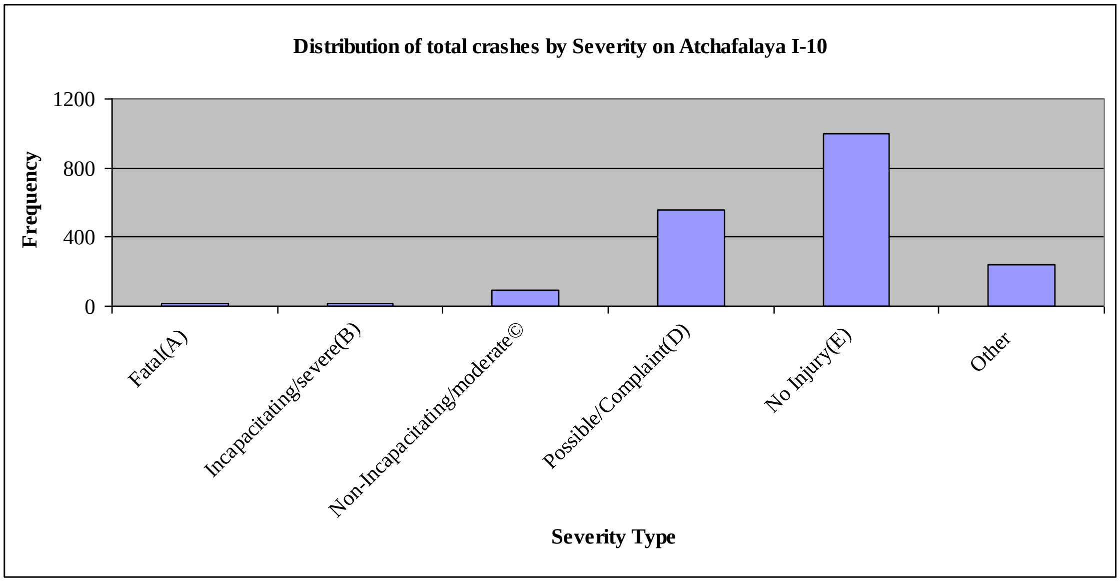
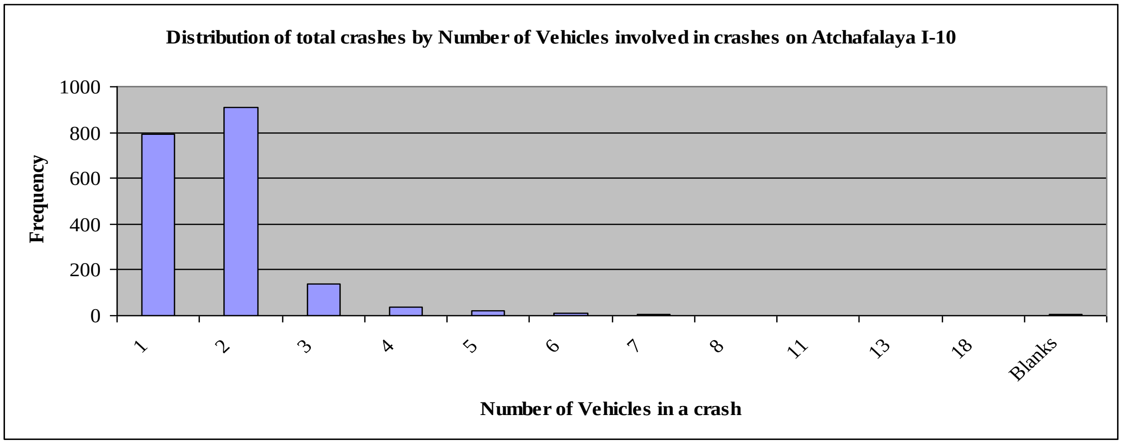
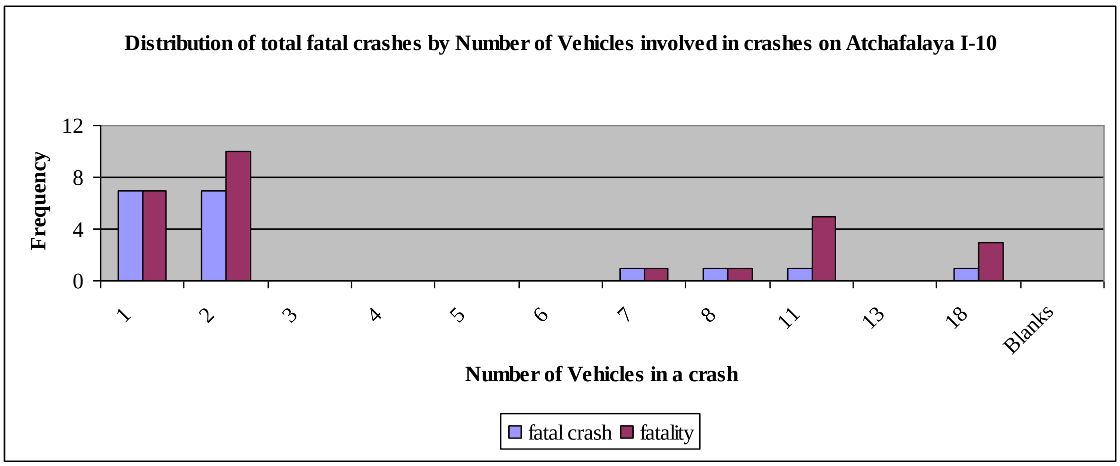


Figure 149
Distribution of crash severity



Total Crashes



(b) Fatal Crashes

Figure 150

Distribution of number of vehicles involved in crashes

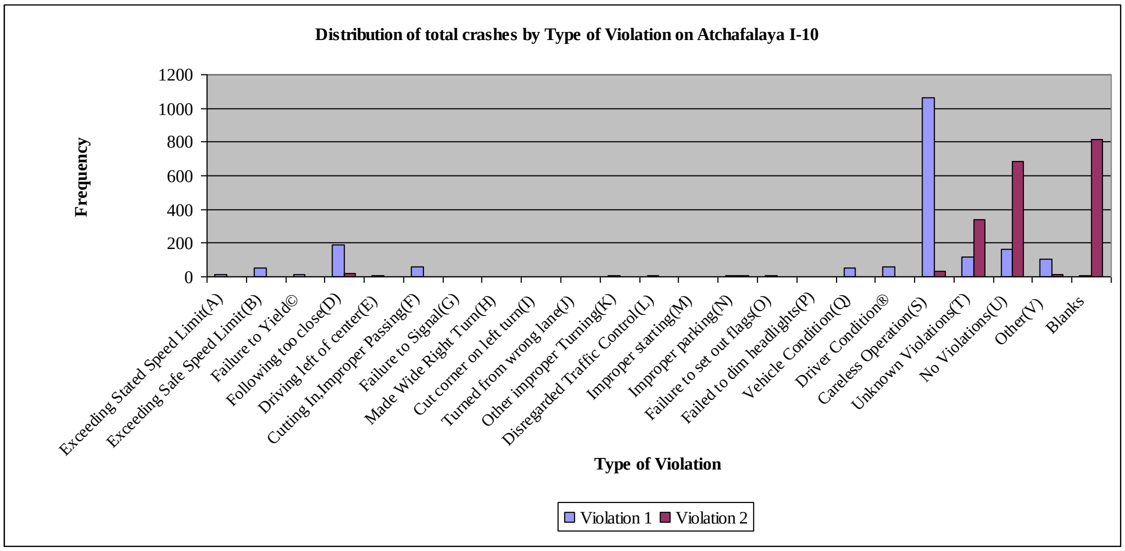


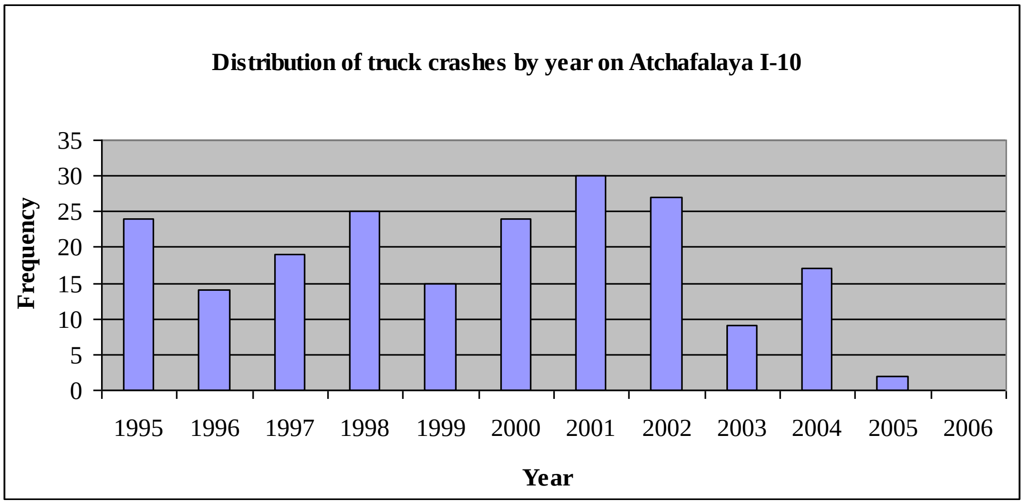
Figure 151
Distribution of type of violations

In summary, the following observations are drawn:

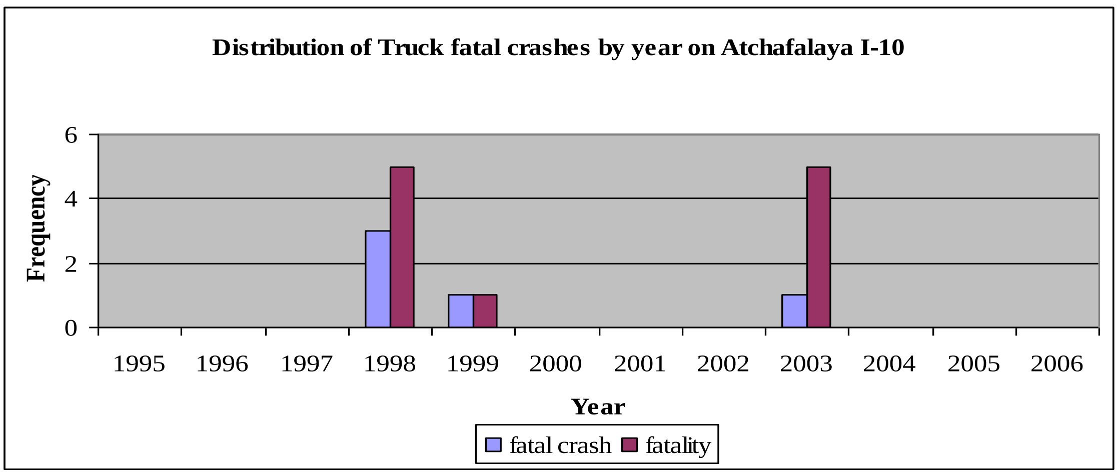
- Highest crash type is collision with other vehicles followed by lane departure (run-off-road) and collision with fixed object.
- Highest type of collision is rear-end that also has higher fatality risk.
- Crashes involved in large vehicles are more fatal than crashes with small vehicles.
- *Careless operation* is the most cited violation followed by *following too close.*

Truck Involvement

Because the DSL and truck lane restriction was established by the concern on the safety problem involved in heavy vehicle, more detailed analysis was conducted on large trucks. The following charts show the truck crash characteristics.



(a) Total Crashes

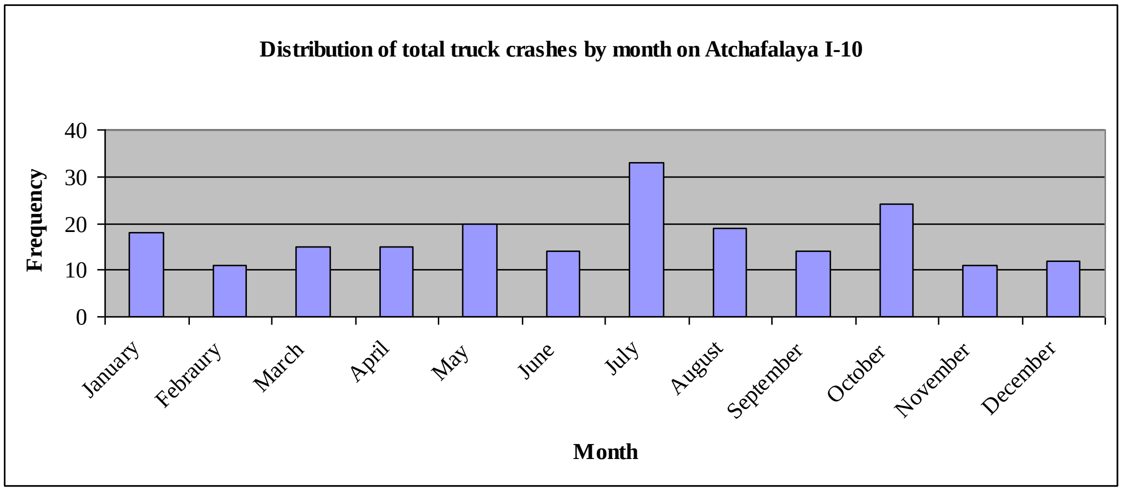


(b) Fatal Crashes

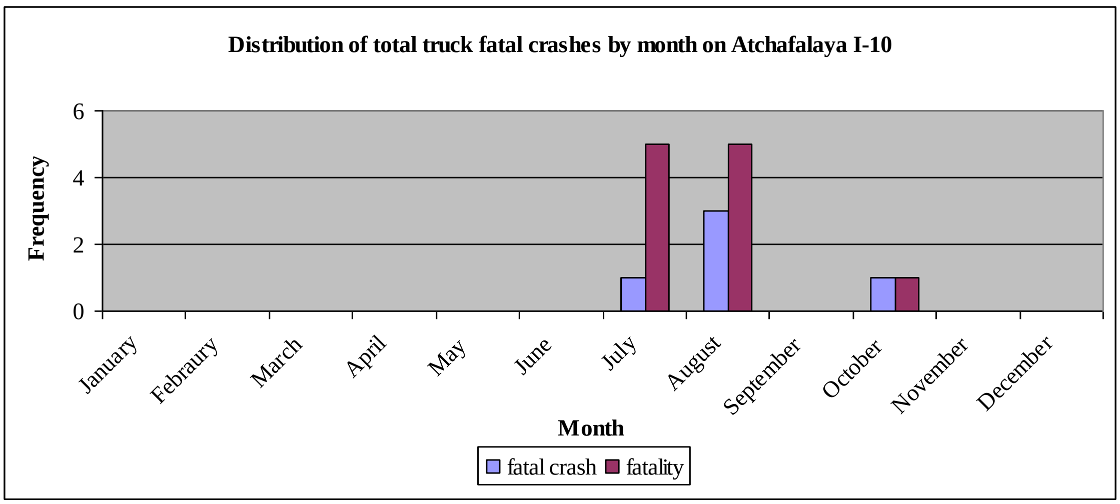
Figure 152
Distribution of truck crashes by year

Table 75
Truck crashes at "before" and "after" periods

	Before (2000-2002)	2003	After (2004-2006)
Number of Accidents	81	9	19
Number of Fatalities	0	5	0
Number of crashes (Vehicle Type 1)	81	9	19
Number of crashes (Vehicle Type 2)	55	9	24
Number of Fatalities (Vehicle Type 1)	0	5	0
Number of Fatalities (Vehicle Type 2)	0	0	0



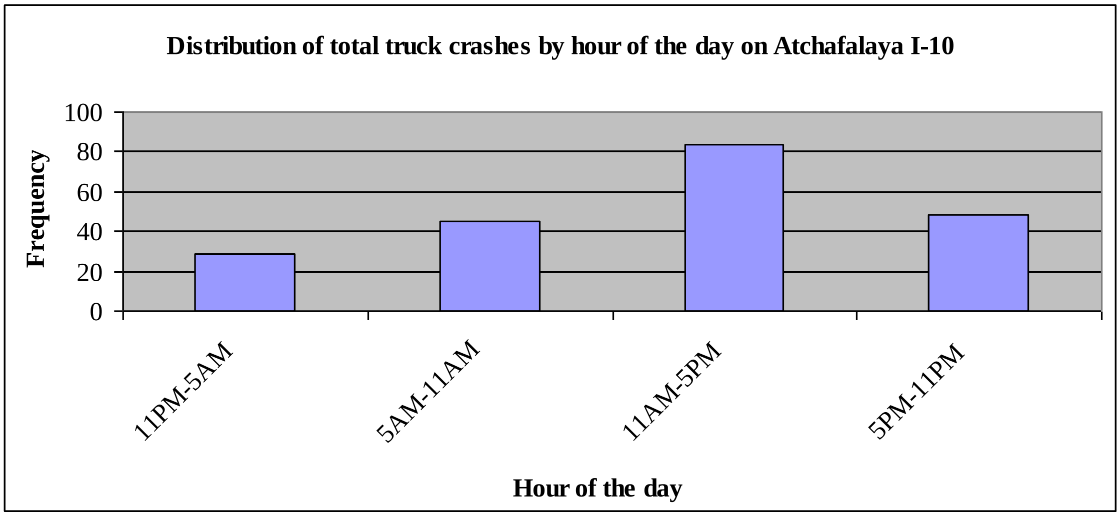
(a) Total Crashes



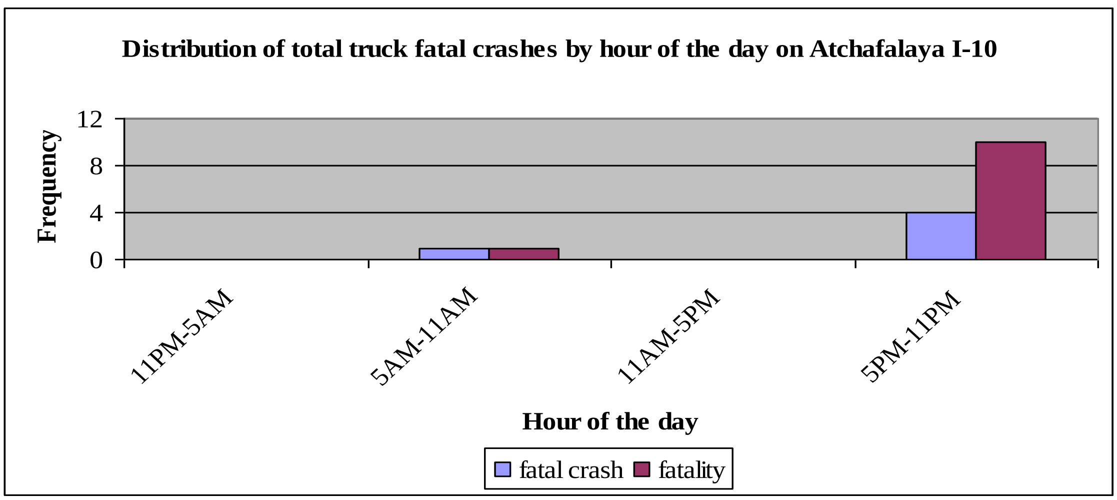
(b) Fatal Crashes

Figure 153

Distribution of truck crashes by month



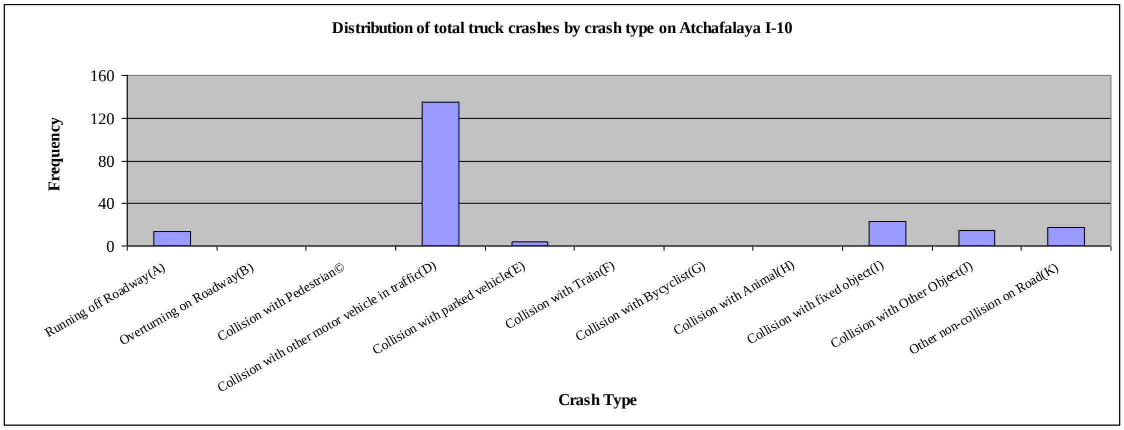
(a) Total Crashes



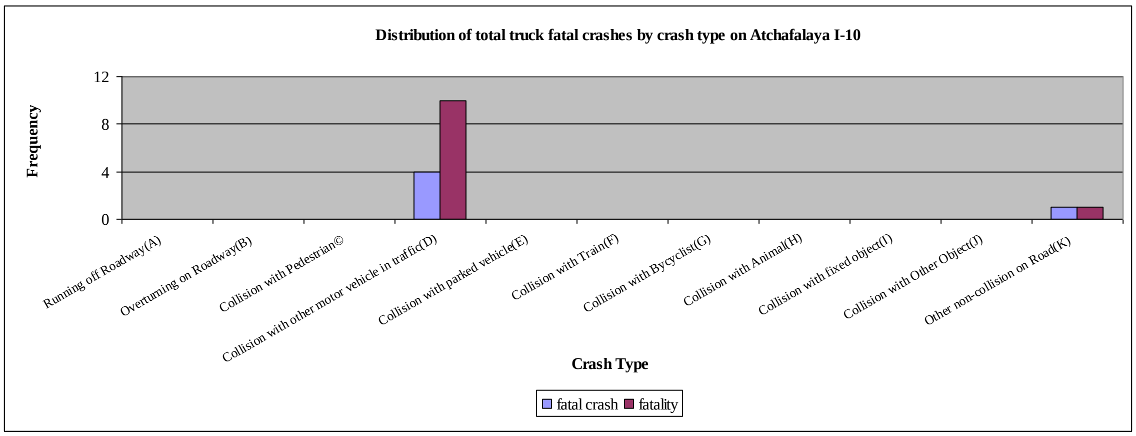
(b) Fatal Crashes

Figure 154

Distribution of truck crashes by period of the day

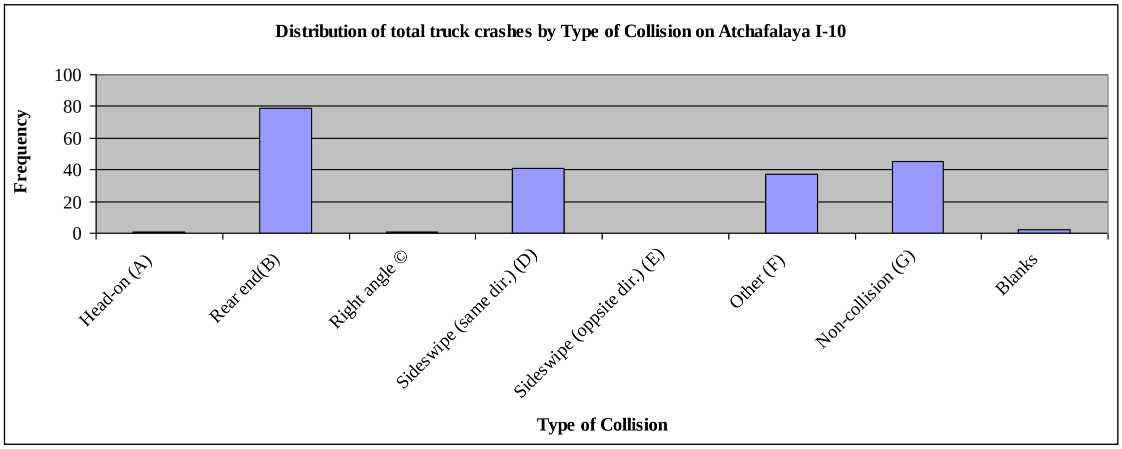


Total Crashes

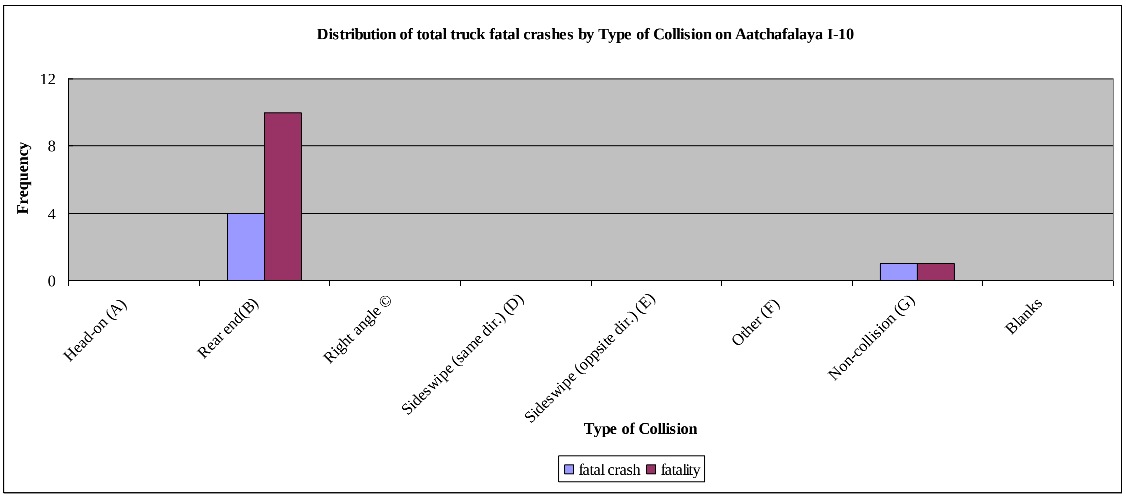


(b) Fatal Crashes

Figure 155
Distribution of truck crashes types



(a) Total Crashes



(b) Fatal Crashes

Figure 156
Type of collision from truck crashes

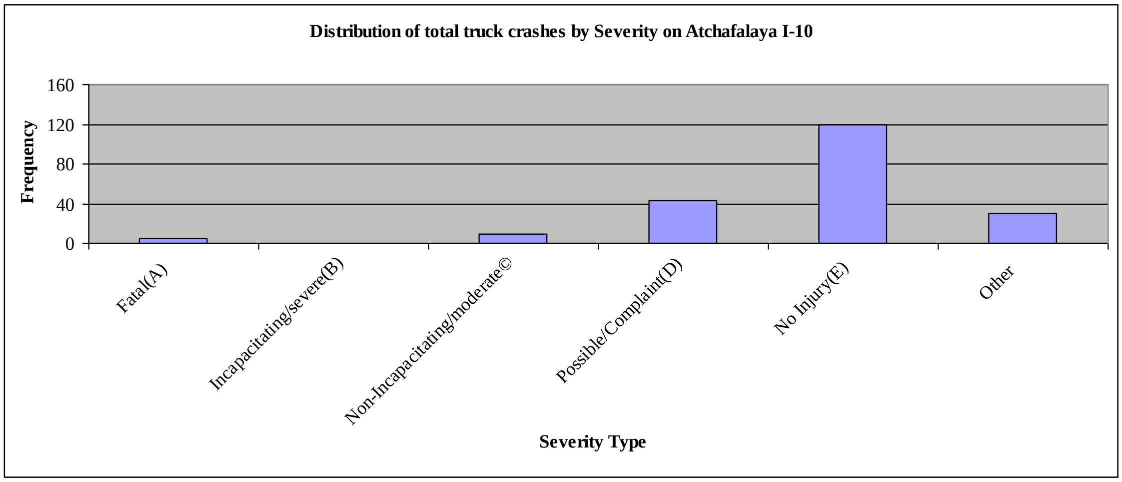
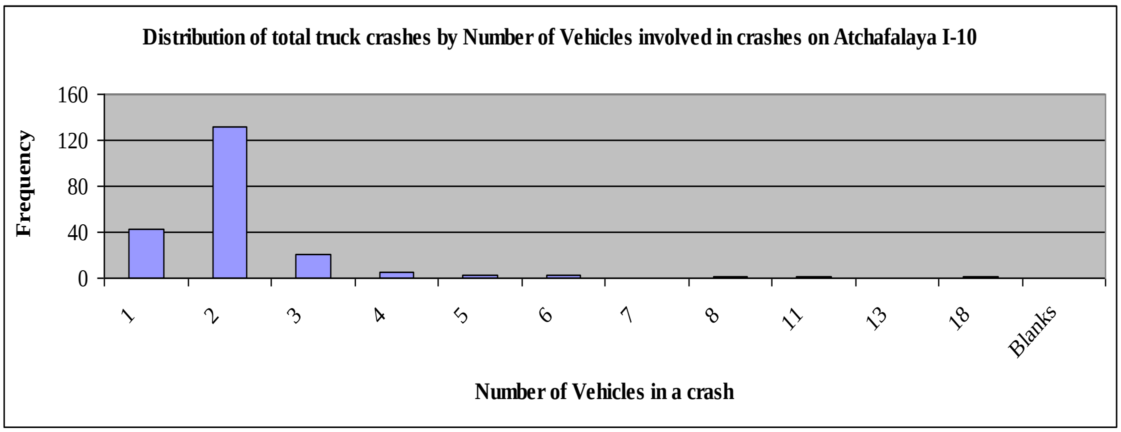
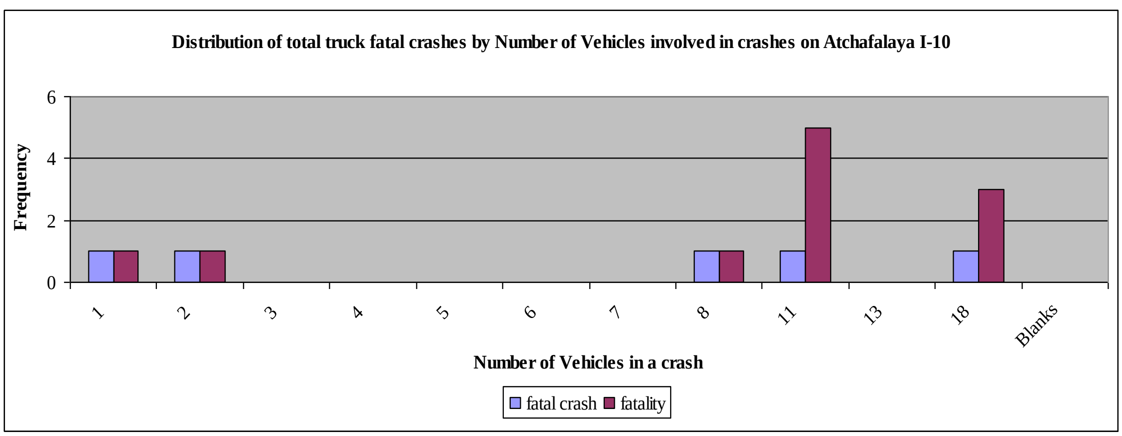


Figure 157
Distribution of truck crash severity



(a) Total Crashes



(b) Fatal Crashes

Figure 158
Number of vehicles involved in truck crashes

In summary, the following observations are drawn for crashes involved trucks:

- A clear reduction in truck crashes by year over the past 12 years.
- Fatal crashes involved trucks are rare events; it only occurred in 1998, 1999, and 2003 during the last 12 years.
- Crash risk is higher in summer.
- More truck crashes happened during 11 a.m. to 5 p.m. time period.
- Highest crash type is rear-end (same as in all vehicles) followed by sideswipe.
- More number of vehicles involved in a single truck accident.

Spatial Distribution

The purpose of the investigation here is to identify the locations with high crash concentration. Generally speaking, locations with high crash concentration indicate a deficiency in highway safety design or a challenging highway design feature that effects safety traffic operation. The following chart shows the number of crashes per mile for the past 12 years.

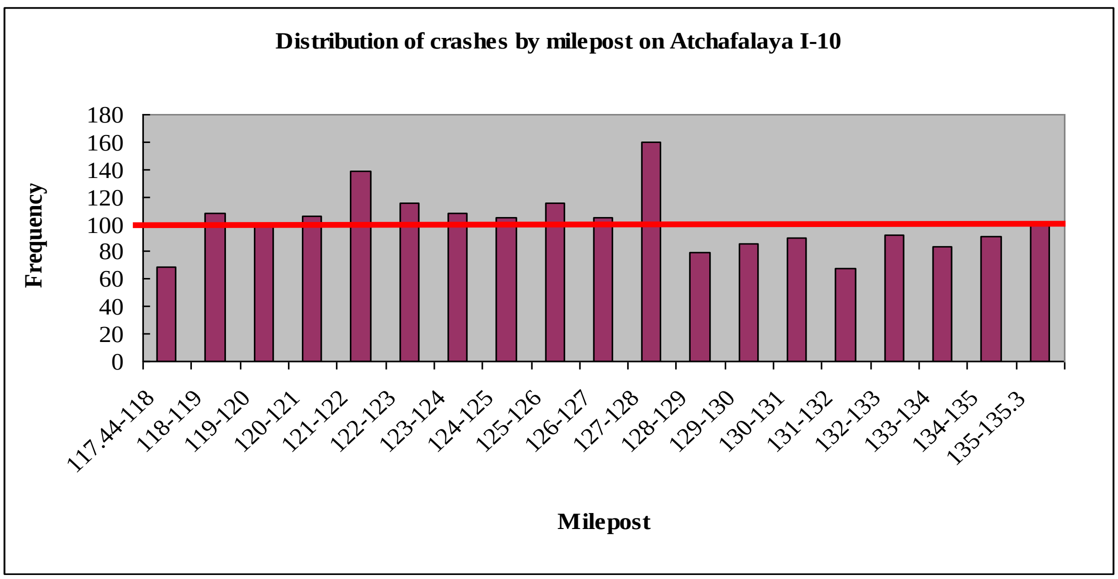


Figure 159
Spatial distribution of crashes by milepost

The average number of crashes per mile over the past 12 years is 100. Clearly, there are two locations with much high number of crashes than the rest, milepost 121-122 and 127-128. The freeway between milepost 120 to 121 has exit and entrance ramps with relatively short acceleration and deceleration lanes due to the limited land use, which presents somewhat challenging operating conditions, and the freeway between milepost 127 and 128 is a narrow, no shoulder high-rise bridge with a smaller sight distance.

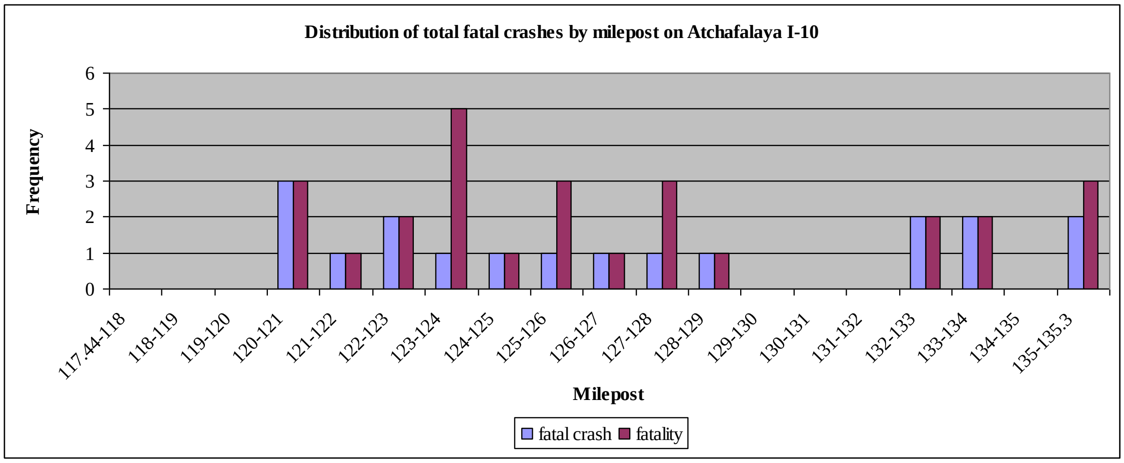


Figure 160
Spatial distribution of fatal crashes by milepost

In summary, the following observations are drawn for spatial distributions of crashes:

- Clearly, there are two locations with higher concentration of crashes (121-122 and 127-128), and each of them has a challenging operating condition caused by the design features limited by the available land use.
- However, their crash characteristics are similar to the whole segment.

Statistical Analysis

With the charts given before, it is clear that both total number of crashes and truck crashes as well as the crash rates decreased after the DSL implementation. However, due to the random nature of crash counts, simply comparing the numbers would not lead to a solid scientific conclusion on the impact of DSL and truck lane restrictions. This section presents the result of a comprehensive statistical analysis. The methodologies used here are mainly from the well-established procedures for highway safety analysis in Ezra Hauer's book "Observational Before-After Studies in Road Safety" (Hauer, 1997).

Two types of before-after statistical studies were performed in this part namely:

1. **Before-after study** – estimating safety before and after at Atchafalaya I-10 segment
2. **Comparison group analysis** – comparing safety at Atchafalaya I-10 with safety at other locations with similar attributes.

The before period is defined as 2000 to 2002 and the after period as 2004 to 2006. The following tables and chart show total number of crashes, fatal crashes, and crashes involving trucks at the before and after periods.

Table 76

Crashes during before and after periods

Period	Year	Crashes	Fatal Crashes	Fatalities	AADT	Crashes	Truck Crashes	Average AADT	Fatal crashes	Fatalities
Before	2000	128	1	1	33,939	537	81	37,542	2	2
	2001	192	0	0	39,271					
	2002	217	1	1	39,415					
	2003	101	2	6	40,918	101	9	41,095	2	6
After	2004	161	2	3	40,540	509	19	40,672	4	5
	2005	170	0	0	40,540					
	2006	178	2	2	40,935					

Table 77

Crashes during before and after periods for type 1 and type 2 vehicles

	Before (2000-2002)	2003	After (2004-2006)
Number of Accidents	81	9	19
Number of Fatalities	0	5	0
Number of crashes (Vehicle Type 1)	81	9	19
Number of crashes (Vehicle Type 2)	55	9	24
Number of Fatalities (Vehicle Type 1)	0	5	0
Number of Fatalities (Vehicle Type 2)	0	0	0

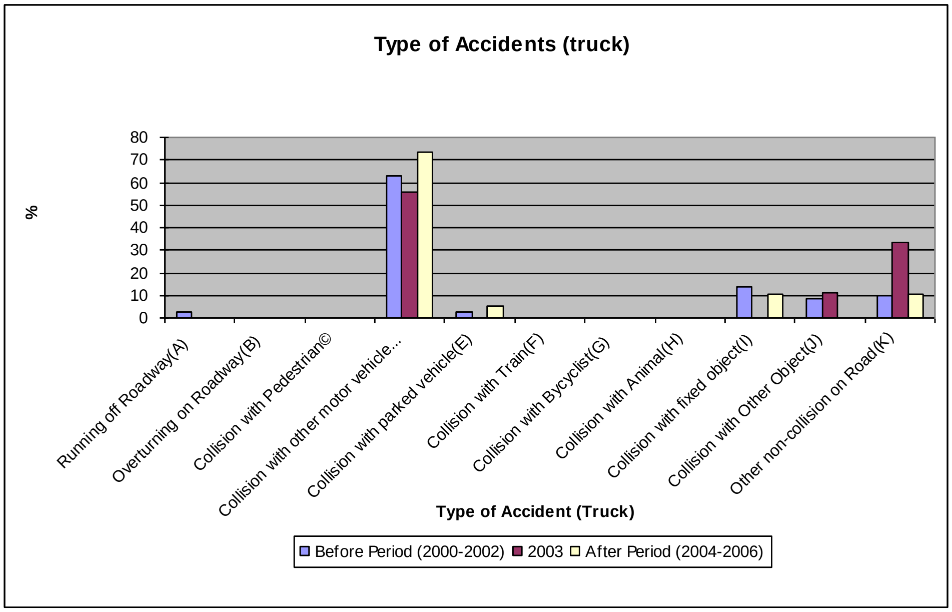


Figure 161

Comparison of crash types during before and after periods

Before-and-after Analysis

Estimated Safety with Naïve Before-After Method: Based on conventional statistical analysis, the relationship between two accident counts (X_1 for before period and X_2 after period) can be used to estimate the expected number of accidents/mile-year for different levels of confidence, when the before and after periods are the same in number of years or units of time. Based on that, required crash count for a desired detectable safety change is:

$$x_2 < x_1 + \frac{k^2}{2} - \frac{k}{2}\sqrt{8x_1 + k^2} \qquad (15)$$

where,

x_1 = accident count for before period,

x_2 = accident count for after period, and

k = 1, 2, or 3 depending on desired confidence level.

The following tables list the results of this analysis for total crashes and truck crashes.

Table 78

Results of naïve before and after analysis for total crashes

	Before-After Study After speed impact of 55mph for truck in September 2003(I-10 Atchafalaya milepost 117.44-135.3)			
	A	B	C	D
1			Input	
2			Before (Year 2000-2002)	After(Year 2004-2006)
3	Miles or Units		17.86	17.86
4	Years		3	3
5	Accidents/(Mile-Year) or Accidents/Unit		10.0	9.5
6	Total Before Accidents	Interim computations	537	509
7	c2/c1 (mile-year)		1	
8		Output		
9		Somewhat Confidently Detectible	Confidently Detectible	Virtually Certainly Detectible
10	K	1	2	3
11	Required number of 'After' Accidents to detect a difference (x2)	505	473	443
12	Required number of 'After' accidents /(Mile-Year) or Accidents/Unit	9.42	8.84	8.27
13	Detectible After-to-Before Ratio of expected values (θ=u2/u1)	0.94	0.88	0.83

Table 79

Results of naïve before and after analysis for truck crashes

Before-After Study After speed impact of 55mph for truck in September 2003(I-10 Atchafalaya milepost 117.44-135.3)			
A	B	C	D
		Input	
		Before (Year 2000-2002)	After(Year 2004-2006)
Miles or Units		17.86	17.86
Years		3	3
Accidents/(Mile-Year) or Accidents/Unit		1.51	0.35
Total Before Accidents	Interim computations	81	19
c2/c1 (mile-year)		1	
	Output		
	Somewhat Confidently Detectible	Confidently Detectible	Virtually Certainly Detectible
K	1	2	3
Required number of 'After' Accidents to detect a difference (x2)	69	57	47
Required number of 'After' accidents /(Mile-Year) or Accidents/Unit	1.29	1.06	0.88
Detectible After-to-Before Ratio of expected values (θ=u2/u1)	0.85	0.70	0.58

Based on the results of the statistical analysis, it is virtually certain that there is a reduction in truck crashes, and somewhat confident in the reduction in total number of crashes between the "before" and "after" time periods.

Using three years crashes in the evaluation reduces the effect of regression-to-the-mean, but it does not account for the changes of other safety factors, i.e., traffic volume during before and after periods. As shown in Table 80, the AADT increased about 7,000, from 2000 to 2006. Traffic volume is one important “exposure” factor along with other factors such as weather patterns and driver behaviors that affect highway safety. Some of these factors are quantifiable and others are not. Although the quantifiable relationship between traffic volume and expected number of crashes is not exactly linear, it is clear that higher traffic volume always causes a higher expected number of accidents on any given highway facility, segment, or intersection. Thus, one obvious big weakness of the above analysis is the ignorance of traffic.

The objective of an observational before-after study is to evaluate a treatment when the roadways or facilities are unchanged except for the implementation of the treatment. In this case the treatment is DSL and truck lane restriction. However, it is impossible to control the changes of other factors. In principle, the true impact of a treatment should be the difference between the predicted safety after the treatment and the predicted safety at after period if the treatment were not implemented.

Much research has been conducted on safety prediction models. Developing a statistically valid and applicable highway safety prediction mode or highway safety performance function (SPF) is not a trivial task. The upcoming Highway Safety Model (HSM) will include three such models for rural two-lane highways, rural multi-lane highways, and urban and suburban arterial highways. These models predict safety, i.e., the expected number of crashes, as a function of a host of variables including the most influential one, AADT.

Since no credible SPF for freeways is available at present, the safety during the after period if DSL were not implemented at the site is estimated. The two different ways to estimate the “after” safety if DSL were not implemented lead to two similar conclusions but with different crash reduction numbers. The application of these two methods is introduced next.

Estimating the Safety Impact with Method One

To account for the change in traffic volume, the following “Four-Step” procedure from Hauer’s book was used in estimating the safety before and after DSL installation with the data given in Table 76 (Hauer, 1997 and 2000).

Table 80
Accident count and average AADT for the study section

	Accident count	Average AADT
3 years Before	K=537	37542
3 years After	L=509	41095

Step One: Estimating the safety if DSL were not installed during after period, $\hat{\pi}$, and the safety after DSL installation $\hat{\lambda}$,

In this case, $\hat{\lambda}$ =L

$$\hat{\pi} = \hat{r}_{tf} K \tag{16}$$

where,

$\hat{\lambda}$: estimated expected number of crashes in the after period with DSL implementation,

$\hat{\pi}$: estimated expected number of accidents in the "after" period if DSL were not used,

$\hat{r}_{tf} = \hat{A}_{avg} / \hat{B}_{avg}$: the traffic flow correction factor,

$\hat{A}_{avg}$: the average traffic flow during the "after" period, and

$\hat{B}_{avg}$: the average traffic flow during the "before" period.

In this application, the value of $\hat{\lambda}$ is 509, the value of $\hat{r}_{tf}$ is calculated as 1.090, and the value of $\hat{\pi}$ is calculated as 586.

Step Two: Estimating $V\hat{A}R\{\hat{\lambda}\}$ and $V\hat{A}R\{\hat{\pi}\}$

$$V\hat{A}R\{\hat{\lambda}\} = L \tag{17}$$

$$V\hat{A}R\{\hat{r}_{tf}\} = r_{tf}{}^{2}(v^{2}\{\hat{A}_{avg}\} + v^{2}\{\hat{B}_{avg}\}) \tag{18}$$

$$V\hat{A}R\{\hat{\pi}\} = (r_{d})^{2}[(\hat{r}_{tf})^{2} K + K^{2} V\hat{A}R\{\hat{r}_{tf}\}] \tag{19}$$

where,

$V\hat{A}R\{\hat{\lambda}\}$: estimated variance of the estimated expected number of crashes in the after period,

v: the percent coefficient of variance for AADT estimates,

$$\mathrm{v} = 1 + 7.7/\,(\text{number of count-days}) + 1650/\mathrm{AADT}^{0.082} \tag{20}$$

$V\hat{A}R\{\hat{\pi}\}$: estimated variance of the estimated expected number of accidents in the "after" period if DSL were not used.

In this application, the value of $V\hat{A}R\{\hat{\lambda}\}$ is 509, the value of $v\{\hat{A}_{avg}\}$ is calculated as 0.0128, the value of $v\{\hat{B}_{avg}\}$ is calculated as 0.0130, the value of $V\hat{A}R\{\hat{r}_{tf}\}$ is calculated as 0.0004, and the value of $V\hat{A}R\{\hat{\pi}\}$ is calculated as 752.79.

Step Three: Estimating the difference $\hat{\delta}$ and the ratio $\hat{\theta}$.

$$\hat{\delta} = \hat{\pi} - \hat{\lambda} \tag{21}$$

$$\hat{\theta} = (\hat{\lambda} / \hat{\pi}) / [1 + \hat{VAR}\{\hat{\pi}\} / \hat{\pi}^2] \tag{22}$$

where,

$\hat{\delta}$: estimated safety impact of DSL, and

$\hat{\theta}$: estimated unbiased expected crash modification factor

In this application, the value of $\hat{\delta}$ is calculated as 77, and the value of $\hat{\theta}$ is calculated as 0.87.

$$\hat{\sigma}\{\hat{\delta}\} = \sqrt{\hat{VAR}\{\hat{\pi}\} + \hat{VAR}\{\hat{\lambda}\}} \tag{23}$$

Step Four: Estimating the variance of $\hat{\delta}$ and $\hat{\theta}$.

$$\hat{\sigma}\{\hat{\theta}\} = \hat{\theta}\sqrt{\hat{VAR}\{\hat{\lambda}\} / \hat{\lambda}^2) + (\hat{VAR}\{\hat{\pi}\} / \hat{\pi}^2)} / (1 + \hat{VAR}\{\hat{\pi}\} / \hat{\pi}^2) \tag{24}$$

In this application, the value of $\hat{\sigma}\{\hat{\delta}\}$ is calculated as 35.52, and the value of $\hat{\sigma}\{\hat{\theta}\}$ is calculated as 0.06.

The interpretation is: the predicted crash reduction is 77 in three years, or 16 percent with DSL and truck lane restriction based on the more accurate statistical B-A analysis method. Following the same procedure, the predicted truck crash reduction is 69 in three years, or 79 percent with the DSL and truck lane restriction.

Comparison Group Analysis (Estimating the Safety Impact with Methods Two)
The second method of statistical analysis is called comparison group method. The difference from the last one is that it estimates "after" safety if DSL were not implemented based on the safety comparison of other freeways. Because of the considerable number of wet lands and swamps along the state coastal area, Louisiana has five elevated freeways including Atchafalaya I-10. They are: I-10 over the Bonnet Carre Spillway (milepost 210 to 221.5), I-10 New Orleans East Twin Spans (milepost 255.4 to 261.3), I-55 over the Manchac Swamp (milepost 0 to 23), and I-310 over the Labranche Wetlands (milepost 0 to 5). Due to the differences in length and traffic volume, crash rate is used for safety comparison among the five elevated freeways. As shown in Figure 162, a crash rate at the Atchafalaya I-10 is slightly higher than the average rate in the before period and is the lowest in the after period.

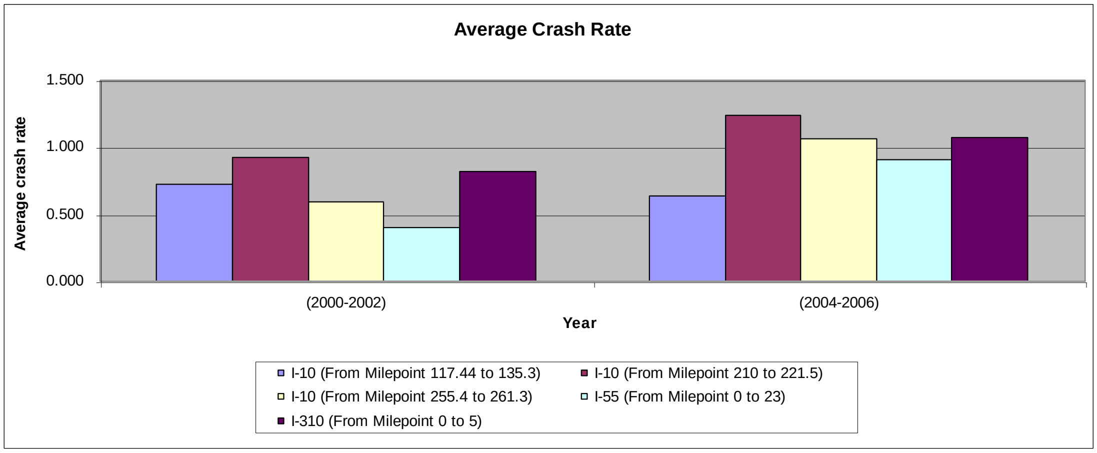


Figure 162
Crash rates at five elevated freeways in Louisiana

Following the "Four-Step" procedure and the data given below, the impact of safety is estimated.

Table 81
Comparison between the study section and other elevated sections

	Atchafalaya I-10 with DSL	Comparison Group (other 4 elevated highways)
Before	K=537	M=1185
After	L=509	N=2002

Step One: Estimating $\hat{\lambda}$ and $\hat{\pi}$.

$$\hat{\lambda} = L \tag{25}$$

$$\hat{\pi} = \hat{r}_T K \tag{26}$$

$$\hat{r}_T = \hat{r}_C = (N/M)/(1+1/M) = N/M \tag{27}$$

where,

$\hat{\lambda}$: estimated expected number of crashes in the after period,

$\hat{\pi}$: estimated expected number of accidents in the "after" period if DSL were not implemented,

$\hat{r}_T$: estimated ratio of the expected accident counts for the treatment group, and

$\hat{r}_C$: estimated ratio of the expected accident counts for the comparison group.

In this application, the value of $\hat{\lambda}$ is 509, the value of $\hat{r}_T$ is calculated as 1.688, and the value of $\hat{\pi}$ is calculated as 906. Here the important assumption is $\hat{r}_C$ equals to $\hat{r}_T$.

Step Two: Estimating $\hat{VAR}\{\hat{\lambda}\}$) and $\hat{VAR}\{\hat{\pi}\}$).

With the same assumption that number total crashes follows Poisson distribution, there is:

$$\hat{VAR}\{\hat{\lambda}\} = L \quad (28)$$

$$\hat{VAR}\{\hat{\pi}\} = \hat{\pi}^2[1/K + \hat{VAR}\{\hat{r}_T\}/\hat{r}_T^{\ 2}] \quad (29)$$

$$\hat{VAR}\{\hat{r}_T\}/\hat{r}_T^{\ 2} = 1/M + 1/N + \hat{VAR}\{\omega\} \quad (30)$$

$$\hat{VAR}\{\omega\} = s^2\{o\} - (1/K + 1/L + 1/M + 1/N) \quad (31)$$

$$m(o) = \sum_{i=1}^{n} o_i / n \quad (32)$$

$$o = (KN)/(LM)/(1 + 1/L + 1/M) \quad (33)$$

$$s^2(o) = (o_i - m(o))^2 \quad (34)$$

where,

$\hat{VAR}\{\omega\}$: the variance of the odds ratios,

o: sample odds ratio,

m(o): the sample mean, and

$s^2\{o\}$: sample variance.

Table 82

Comparison between the study section and other elevated sections (2000-2006)

Year	Atchafalaya	Other four elevated highways	Oi	m(o)	s2{o}
2000	128	359			
2001	192	393	0.724	1.176	0.204
2002	217	433	0.968	1.176	0.043
2004	161	523	1.614	1.176	0.192
2005	170	556	0.999	1.176	0.031
2006	178	923	1.574	1.176	0.158
Average	174	531			0.126

In this application, the value of $\hat{VAR}\{\hat{\lambda}\}$ is 509, the value of $\hat{VAR}\{\omega\}$ is calculated as 0.1106, and the value of $\hat{VAR}\{\hat{\pi}\}$ is calculated as 93510.9.

Step Three: Estimating the safety impact of $\hat{\delta}$ and $\hat{\theta}$.

$$\hat{\delta} = \hat{\pi} - \hat{\lambda} \tag{35}$$

$$\hat{\theta} = (\hat{\lambda} / \hat{\pi}) / [1 + \hat{VAR}\{\hat{\pi}\} / \hat{\pi}^2] \tag{36}$$

In this application, the value of $\hat{\delta}$ is calculated as 397.5, and the value of $\hat{\theta}$ is calculated as 0.504.

Step Four: Estimating $\hat{\sigma}\{\hat{\delta}\}$ and $\hat{\sigma}\{\hat{\theta}\}$.

$$\hat{\sigma}\{\hat{\delta}\} = \sqrt{\hat{VAR}\{\hat{\pi}\} + \hat{VAR}\{\hat{\lambda}\}} \tag{37}$$

$$\hat{\sigma}\{\hat{\theta}\} = \hat{\theta}\sqrt{\hat{VAR}\{\hat{\lambda}\} / \hat{\lambda}^2) + (\hat{VAR}\{\hat{\pi}\} / \hat{\pi}^2)} / (1 + \hat{VAR}\{\hat{\pi}\} / \hat{\pi}^2) \tag{38}$$

where,

$\hat{\sigma}\{\hat{\delta}\}$: estimated standard deviation of difference between actual number of crashes and the expected number of crashes in the after period on the treatment group; and

$\hat{\sigma}\{\hat{\theta}\}$: estimated standard deviation of the ratio of actual number of crashes and the expected number of crashes in the after period on the treatment group.

In this application, the value of $\hat{\sigma}\{\hat{\delta}\}$ is calculated as 306.6, and the value of $\hat{\sigma}\{\hat{\theta}\}$ is calculated as 0.154.

The interpretation is: the predicted crash reduction is 398 or 50 percent with DSL and truck lane restriction based on the B-A comparison group analysis. Following the same procedure, the predicted truck crash reduction is 30 in 3 years, or 64 percent due to the DSK and truck lane restriction.

Supplementary statistics on the safety analysis are also presented in Appendix D.

Table 83
Summary of the statistical analysis

Method	Reduction in (expected)[1] number of crashes	Reduction in % of Crashes	Reduction in (expected) Truck Crashes	Reduction in % of Truck Crashes
Naïve B-A	28 Somewhat significant	5%	62 Certainly significant	76%
B-A (predicted)	77 (35)	13% (6%)	69 (11)	79% (5%)
B-A with comparison Group (predicted)	398 (307)	50% (15.4%)	30 (38)	64% (12%)

Note:1. as in the last two methods; and 2. the numbers in parentheses is standard deviation of the estimated

Summary

The crash data analysis for the study section clearly showed a reduction in the number of crashes and particularly the number of truck crashes, despite the steady increase in the traffic volume on the Atchafalaya section of I-10 in the past 7 years. The more rigorous statistical analysis further confirmed this observation. Although the results shown differ in magnitude, the basic conclusion was the same. Among the three methods used in the study, the method that accounts for the change in traffic volume of the site with DSL produces the most reliable results because it accounts for change in traffic, and because it produced a smaller standard deviation for the prediction. However, it should be noted that in addition to the differential speed limit policy, there were other improvements made on this study section of the freeway such as shot abrasion and raised pavement markers, which could have also impacted safety during the project study period. The safety impact identified in this study could also be attributed to not only the differential speed limit but also the pavement improvements. While there is no way for researchers to identify precisely the safety impact of each improvement, it was nonetheless evident that the difference in crashes between the before and after time periods was significant.

Therefore, the following conclusions could be drawn:

- There are reductions in the number of total crashes and truck crashes in the “after” time period.
- The reduction on the total number of crashes is also significant based on the scientific statistical before-after analysis.
- Due to changes made to the highway during the analysis period, it is impossible to know whether the differential speed limit and truck lane restriction were responsible for the reduction in crashes on the test section.

CONCLUSIONS AND RECOMMENDATIONS

This study gathered traffic data at four observation sites using remote traffic microwave detectors and examined the traffic characteristics and truck compliance behavior over the 18-mile elevated Atchafalaya segment of I-10, where truck lane restriction and differential speed limit policies were recently applied. Further, crash data were collected after the two restriction policies were implemented and compared with crash data before the implementation to assess the safety impacts of the newly applied policies. In addition, two opinion surveys were conducted to assess truck drivers' perceptions and opinions to such restrictions. The first survey was mailed out to selected trucking companies whose trucks passed through the study section. The second survey was conducted online at the DOTD Web site and was open to all trucking companies.

The basic statistical analyses of the traffic data collected over three months period showed that the speed in the left lane was much higher than it was in the right lane as a result of the imposed differential speed limit. This observation was consistent throughout the day with a slight increase of speed in both lanes during nighttime. In terms of the compliance of trucks to the lane restriction, the results showed more trucks in the right lane than in the left lane, with a compliance rate in the range of 60 percent to 80 percent most of the time. The compliance rate, however, was slightly lower at the first site encountered by vehicles in each direction. Another possible explanation to the relatively high presence of trucks in the left lane is that trucks may also occupy the left lane for overtaking maneuvers in order to pass slower vehicles in the right lane. It is, however, impossible to distinguish between trucks occupying the left lane for passing maneuvers and those in violation of the lane restriction policy. As such, the actual violation rate may be less than that observed by the percentage of trucks in the left lane.

To further evaluate more detailed aspects of the compliance of trucks to the differential speed limit policy, linear regression models were applied to determine the variables with the most significant effect on speed. The models showed significant differences in speed between the right lane and left lane at each site. Speed was also negatively affected by the truck volume, as well as the total traffic volume. To control the effect of vehicle interactions on the traffic speed, regression models were developed for predefined levels of lane occupancy. The results showed that the traffic speed decreased as the percentage of trucks in the traffic stream increased. This implies that the truck speeds were generally lower than the rest of the vehicles because of their reduced speed limit. The compliance to the truck speed limit was further examined using pairwise comparisons between observations with no trucks, mixed traffic composition, and trucks only. The results showed that trucks tended to increase their speed when no other vehicles were present. The speed under each of the three cases was also compared to three values of speeds: 55, 60, and 65 mph. For mixed traffic composition, truck speeds were significantly higher than 55 mph, but lower than 60 mph on the right lanes. The truck speeds, however, tended to exceed 60 mph in the left lane, which implied that trucks violating the lane restriction policy also seemed to violate the speed limit. Similar results were observed for traffic periods with trucks only.

The crash data analysis for the study section clearly showed a reduction in the number of crashes and particularly the number of truck crashes, despite the steady increase in the traffic volume over the Atchafalaya section of I-10 in the past 7 years. The more rigorous statistical analysis further confirmed this observation. Although the results shown differ in magnitude, the basic conclusion was the same. Among the three methods used in the study, the method that accounts for the change in traffic volume of the site with DSL produced the most reliable results because it accounts for change in traffic, and because it produces a smaller standard deviation for the prediction. It should be noted, however, that in addition to the imposed restriction policies there were other improvements made such as shot abrasion and raised pavement markers. Therefore, the safety impact identified in this study could also be attributed to the other pavement improvements.

The mail-out survey and the online web survey yielded many expected and some not-so expected results. Generally, the responses obtained from both surveys to each question were very consistent and nearly identical in many cases, despite the difference in the sample size of each survey. Overall, it was obvious that the truckers were not in favor of the restrictions imposed on their driving. It was also clear that they did not perceive a significant safety benefit was being experienced from the restrictions; rather they tended to view them as an inconvenience to their driving task. In fact, it was apparent that they felt it would be safer to have a more uniform speed and vehicle lane distributions on the study segment. This was an interesting finding since it has been recognized by traffic researchers and practitioners that uniformity of speed promotes both safety and efficiency on freeways. Among the most useful findings, particularly from a design and control standpoint, was that the vast majority of drivers were well-aware of the restrictions along this segment and did not feel an overwhelming need to add more features like incident warnings, current speed displays, or even nighttime illumination. In fact, given the drivers' similarly strong opinions opposing higher degrees of enforcement, it could also be concluded that despite perceptions to the contrary, truckers do not feel that they are a threat to traffic safety and would prefer to be left alone to do their jobs.

Based on the results of this study, the applied differential speed limits and truck lane restriction are effective to some extent on the Atchafalaya segment of I-10. While the truck compliance to both policies seems somewhat acceptable, higher compliance rates could likely be achieved by increasing the level of enforcement along the study segment. It is recommended that a brief study be conducted after a few years to examine the safety impact in terms of crash rates over a longer period of time.

LIST OF ACRONYMS AND ABBREVIATIONS

AADT	Average Annual Daily Traffic
CCTV	Closed-Circuit Television
CV	Coefficient of Variation
DSL	Differential Speed Limits
DTT	Directional-Temporal Plane Transform
EIS	Electronic Integrated Systems
FHWA	Federal Highway Administration
FMCW	Frequency Modulated Continuous Wave
GLM	General Linear Model
HSM	Highway Safety Model
LADOTD	Louisiana State Department of Transportation and Development
LSU	Louisiana State University
LTRC	Louisiana Transportation Research Center
NMSL	National Maximum Speed Limit
PRC	Project Review Committee
RF	Radio Frequency
RTCP	Remote Traffic Counting Package
RTMS	Remote Traffic Microwave Sensors
RVD	Radar Vehicle Detectors
SAS	Statistical Analysis Software
SCDOT	South Carolina Department of Transportation
SPF	Safety Performance Function
SQL	Structured Query Language
SR	State Route
TCP/IP	Transmission Control Protocol/Internet Protocol
VDOT	Virginia Department of Transportation
WATER	Wide Area Traffic Event Reporting

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APPENDIX A

WATER SQL Setup Instructions

This appendix outlines the details required to install (a) SQL Server 2005 Express Edition and (b) EIS WATER/SQL 2.2 on a standalone PC. The tools required for the setup are:

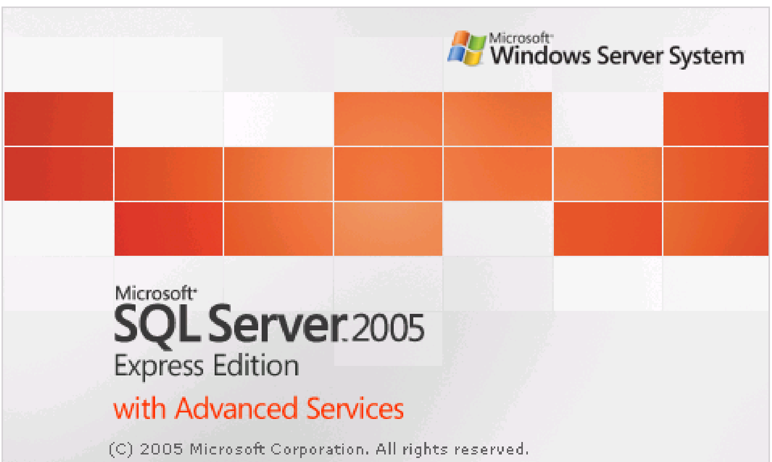
- SQL Server 2005 Express Edition installation CD (downloaded from MS)
- SQL Database setup scripts (from EIS)
- EIS WATER/SQL 2.2 Installer (from EIS)

Installing SQL Server 2005

The setup procedure requires the following steps:

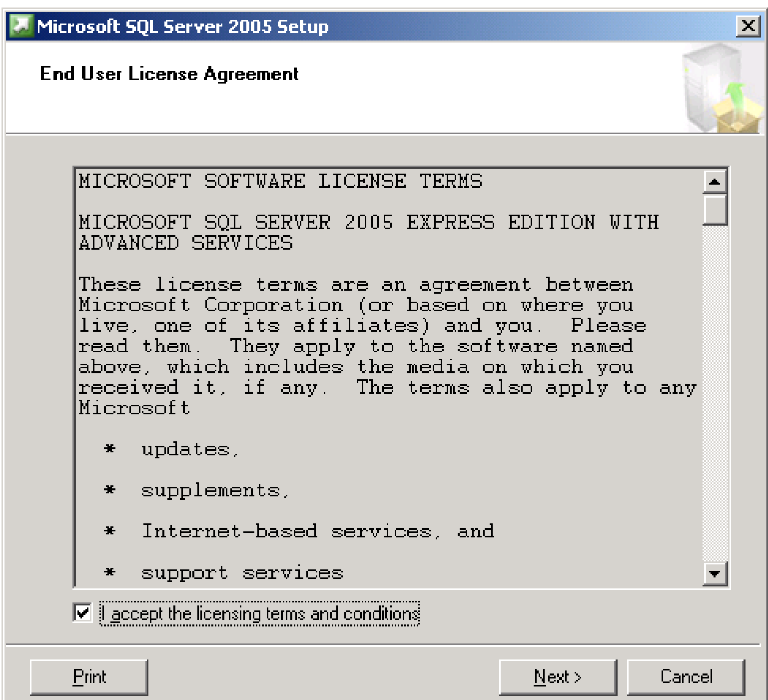
1. Insert SQL installation CD into drive.

SQL Server 2005 Splash Screen

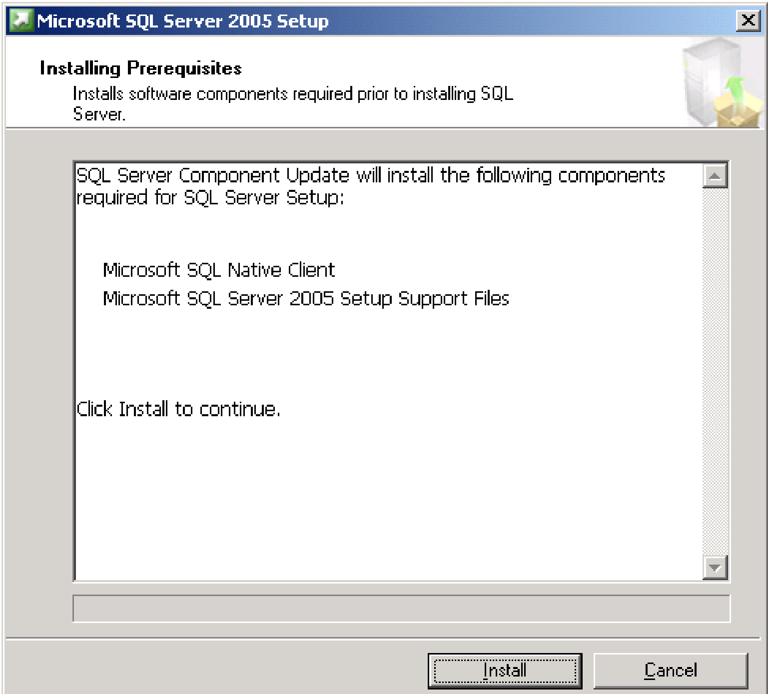


2. Main Install Screen
   - Click Run SQL Server Installation Wizard

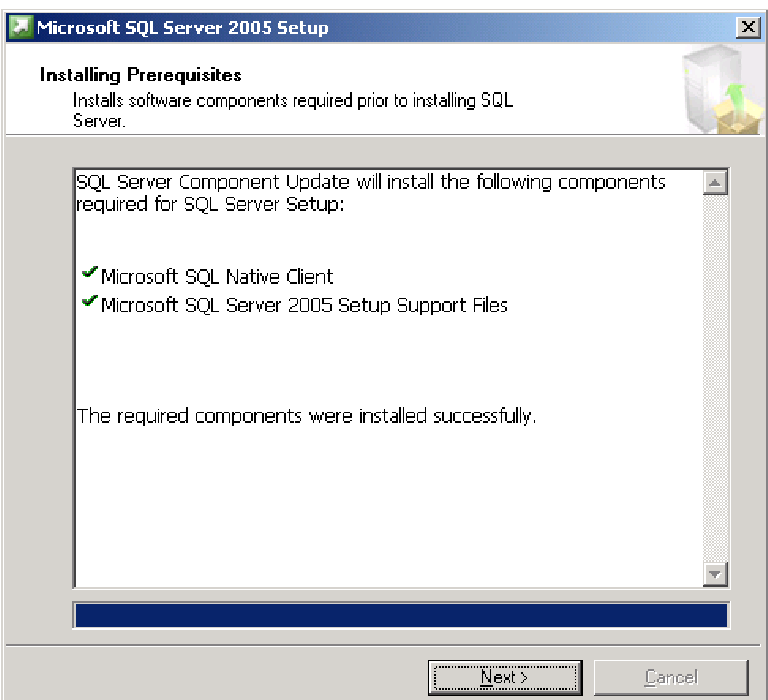
3. End User License Agreement
   - Click Accept, and Next.



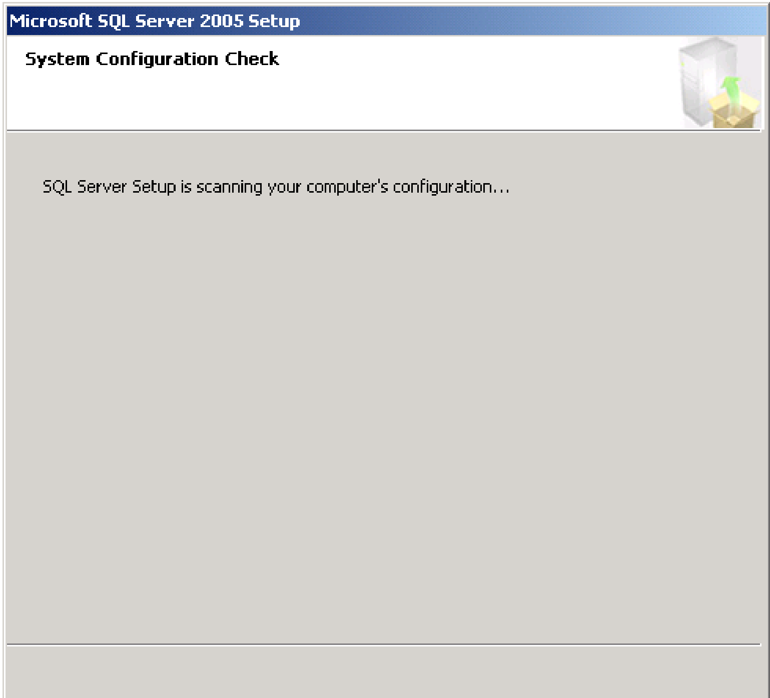
4. Pre-requisites Install
   - Click Install.



5. Pre-requisites Install Complete
   - Click Next.



6. Scanning Computer Configuration

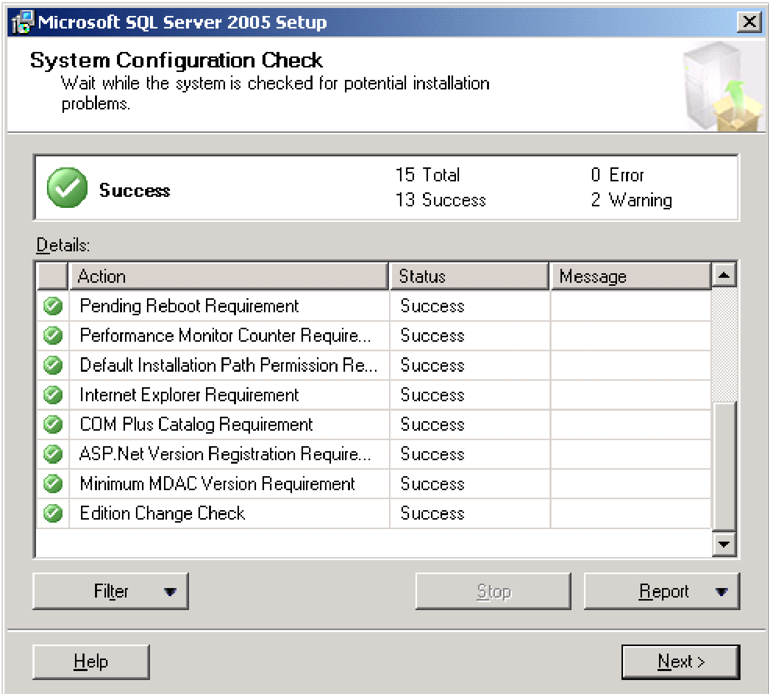


7. Welcome Screen
   - Click Next.

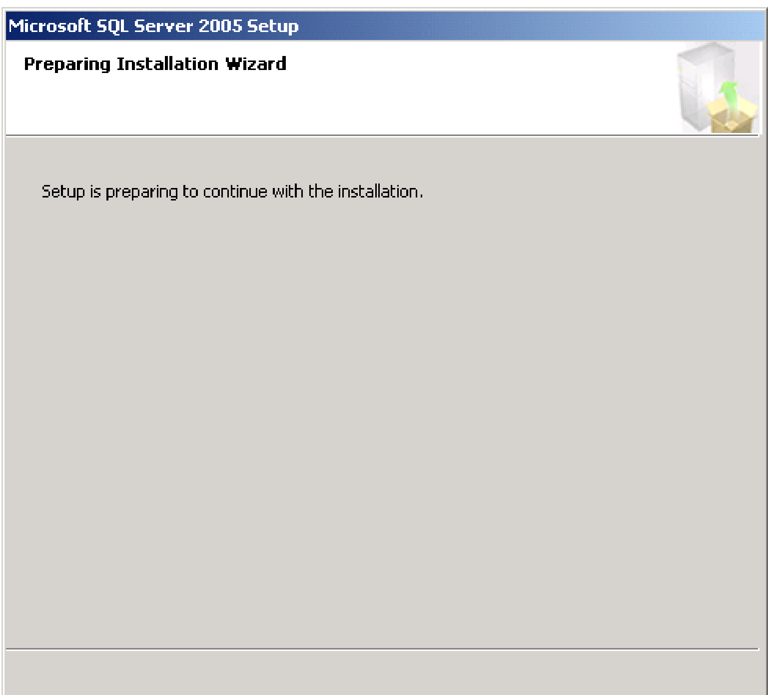
8. System Configuration Check

You may receive warning that you do not meet the Minimum Hardware and IIS Feature requirements. This should not be a problem.

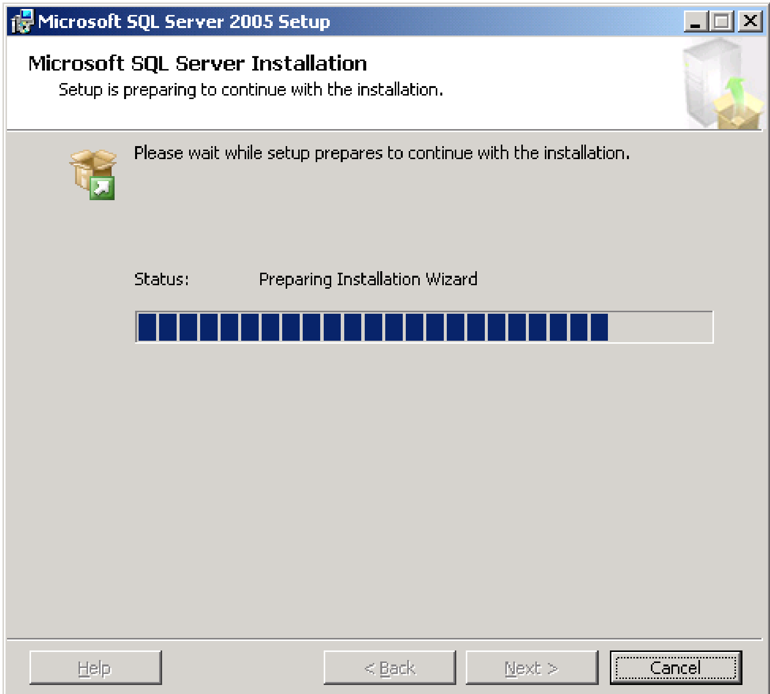
- Click Next



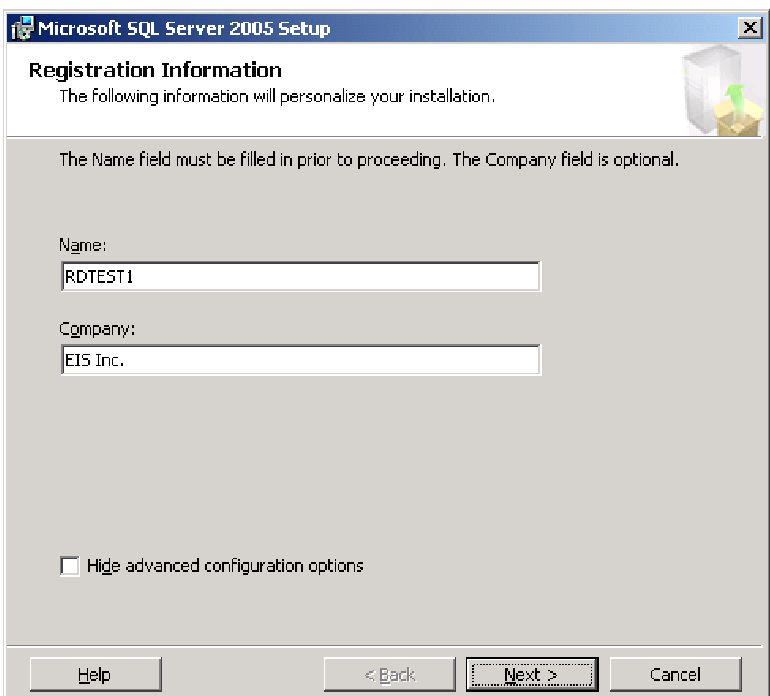
9. Preparing the Installation



Preparing the Installation (continued)



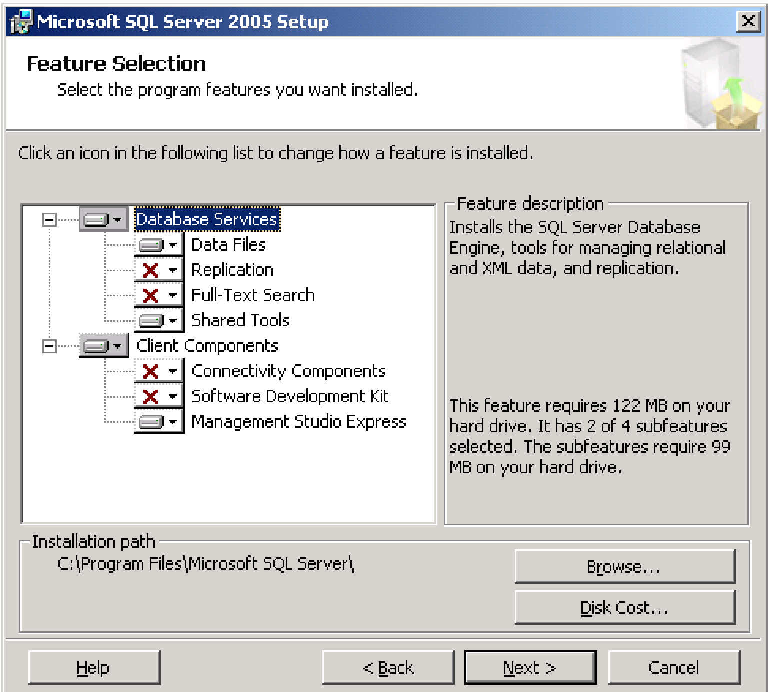
10. Registration Information
    - Deselect Hide Advanced Options.
    - Click Next.



11. Install Features
    - Data Files
    - Shared Tools

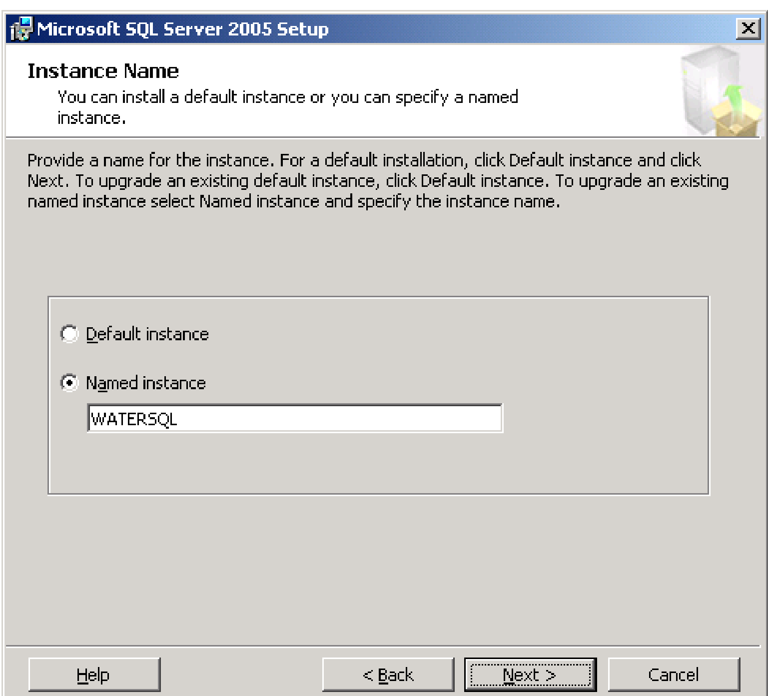
- Management Studio Express

- Click Next.



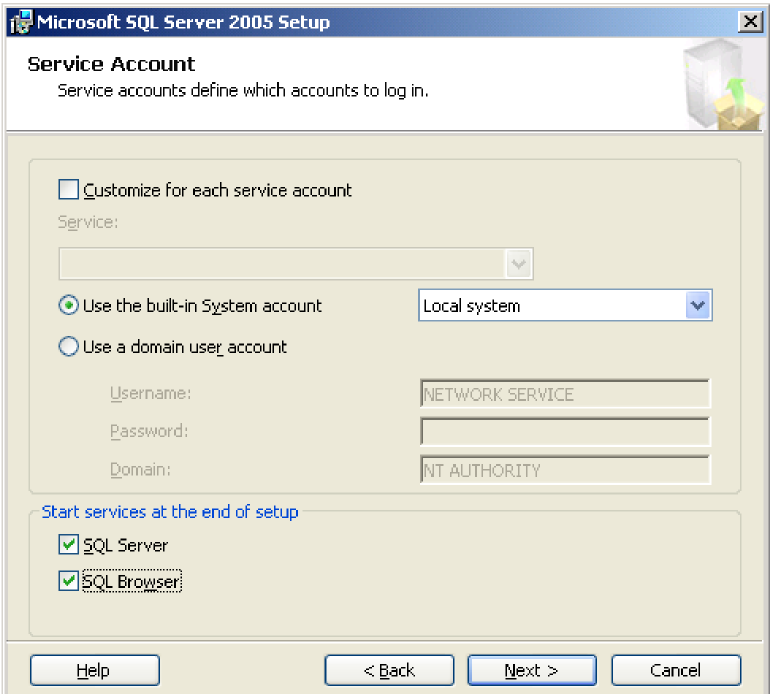
12. Advanced Options (1)

- Select Named Instance and type "WATERSQL."
- Click Next.



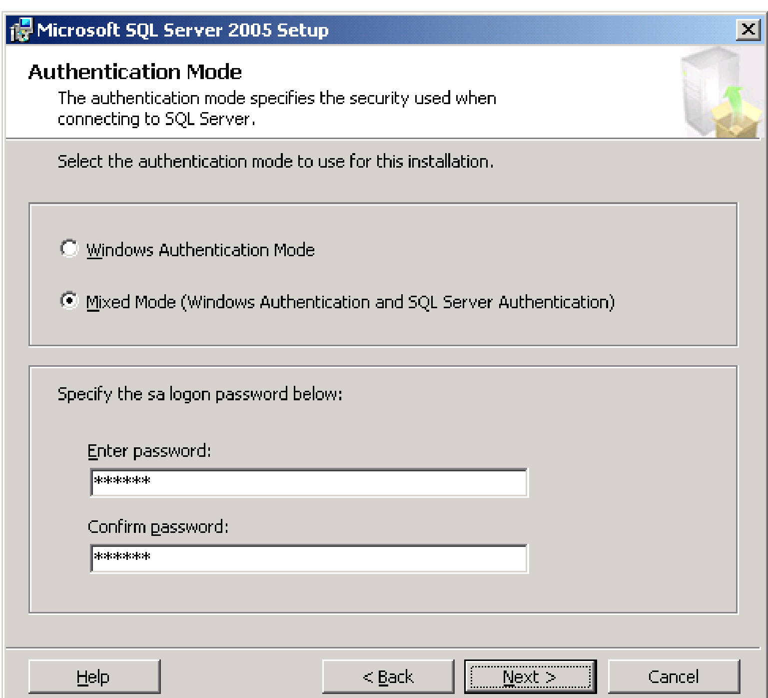
13. Advanced Options (2)

- Use the built-in System Account – Local System.
- Select SQL Server and SQL Browser to startup .
- Click Next.



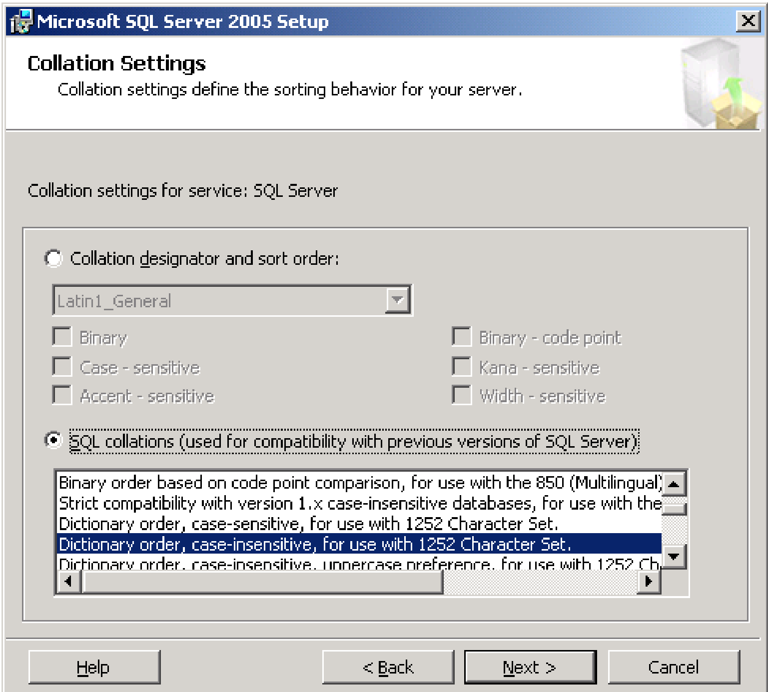
14. Authentication Method

- Select Mixed Mode, SA Password "admin1."
- Click Next.



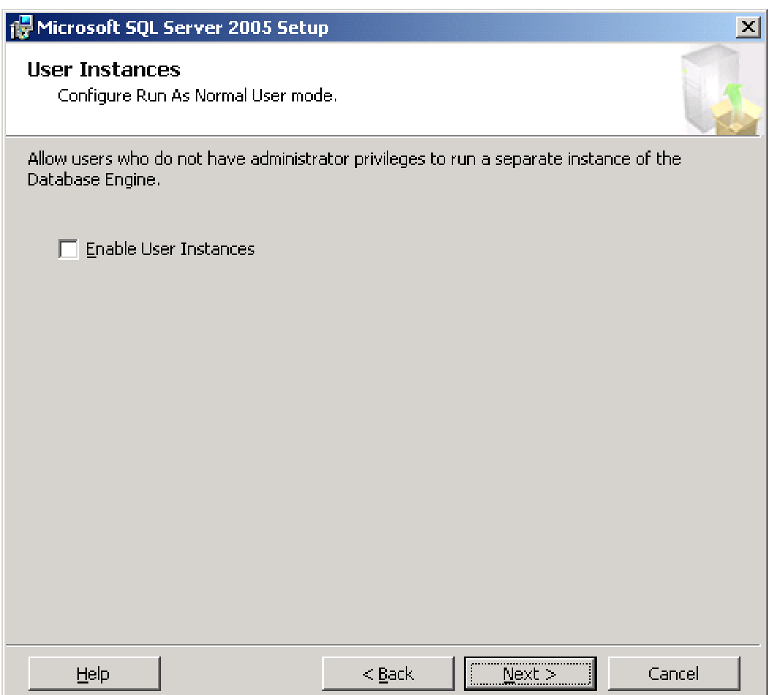
15. Collation Settings

- Leave defaults, click Next.



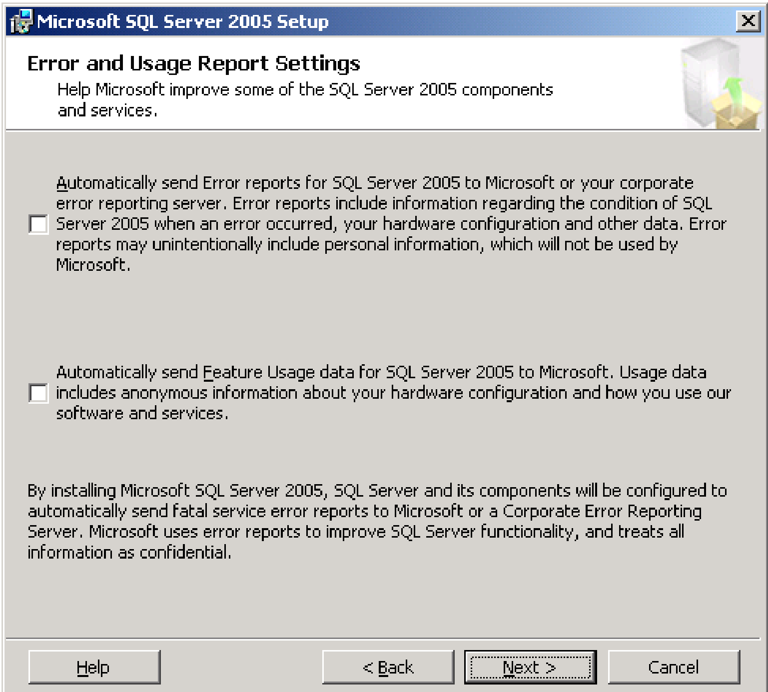
16. Run As Normal User (RANU) aka User Instances

- Deselect "Enable User Instances"
- Click Next.



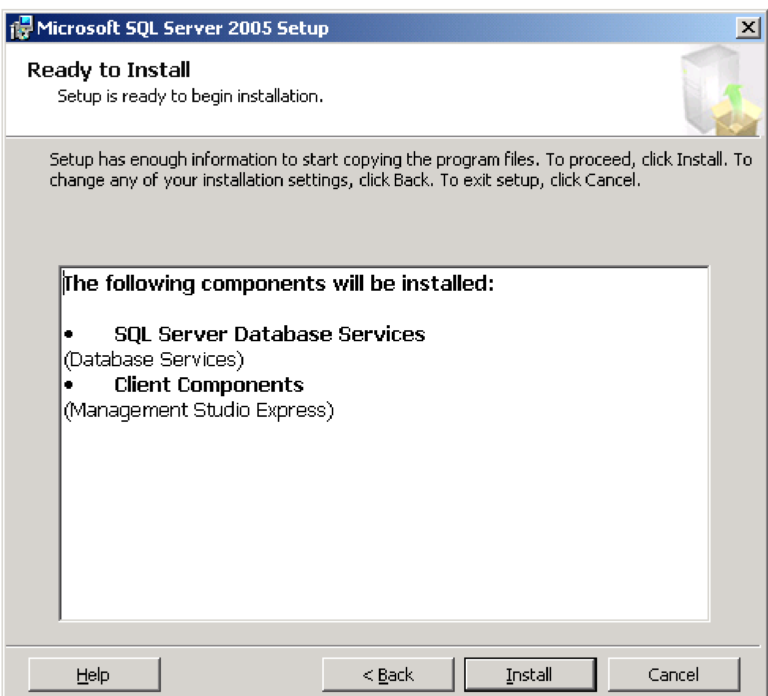
17. Error and Usage Reporting

- Leave defaults, click Next.

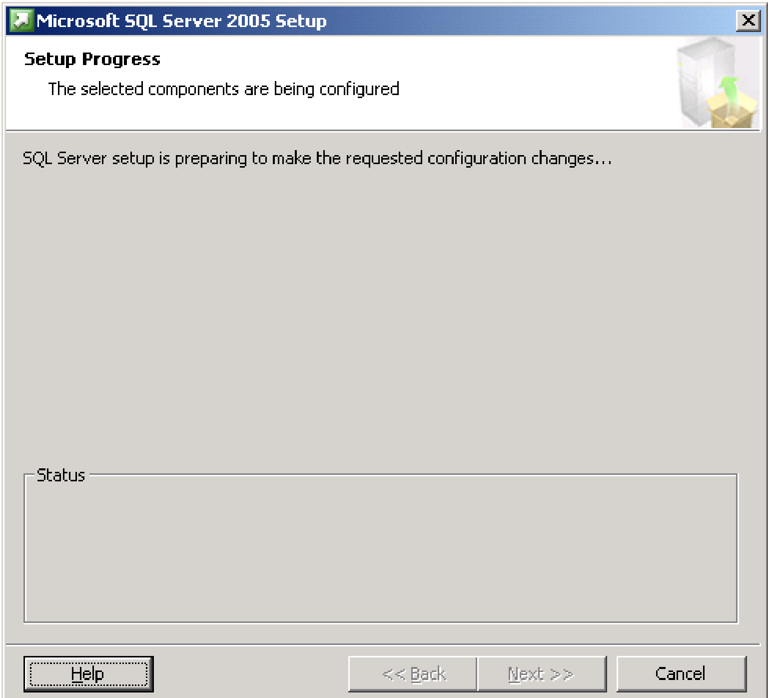


18. Ready to Install

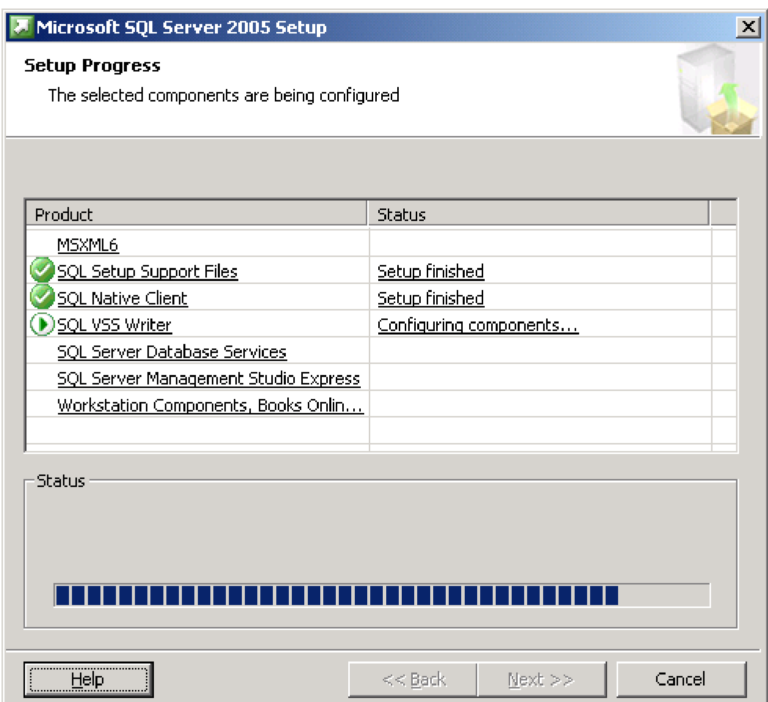
- Click Install.



19. Preparing to Install

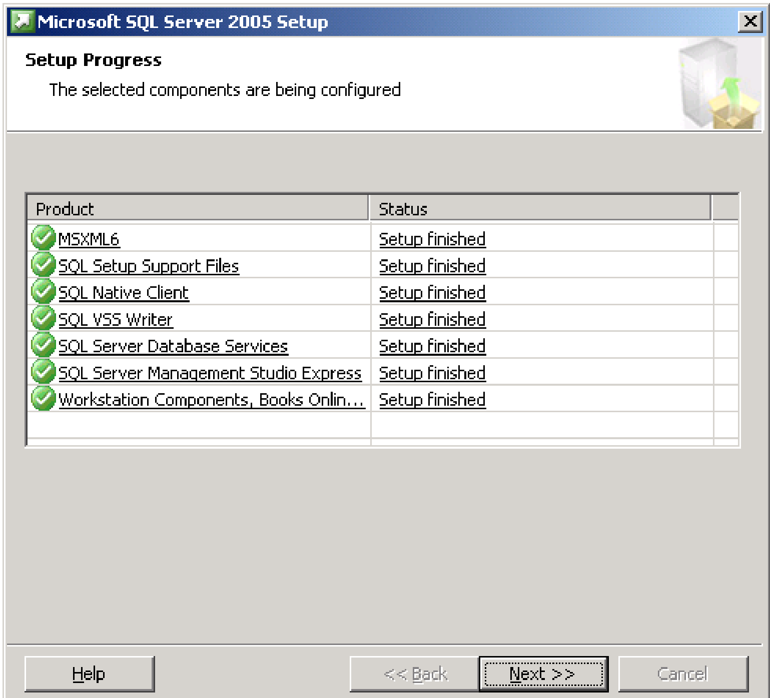


20. Install Progress



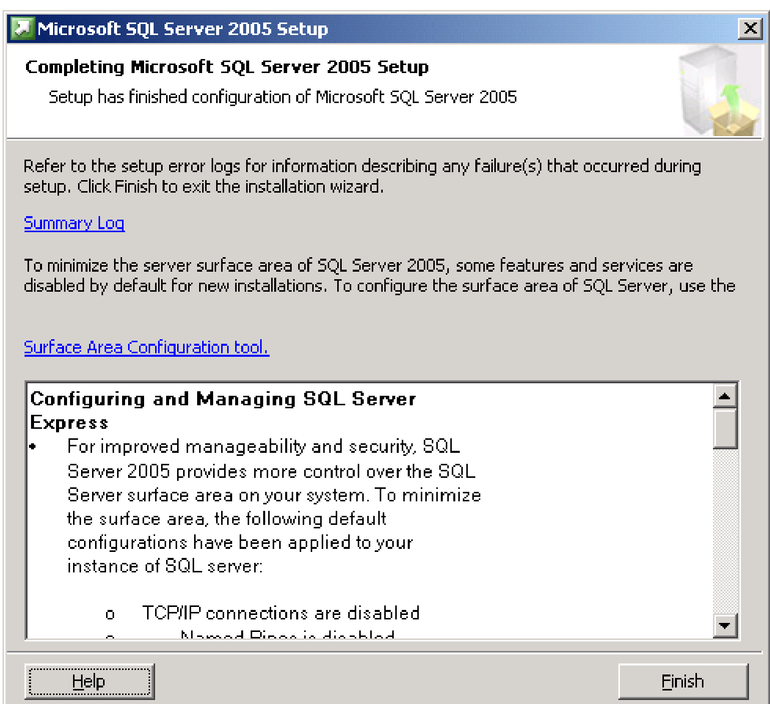
21. Install Complete

- Click Next.



22. Install Summary

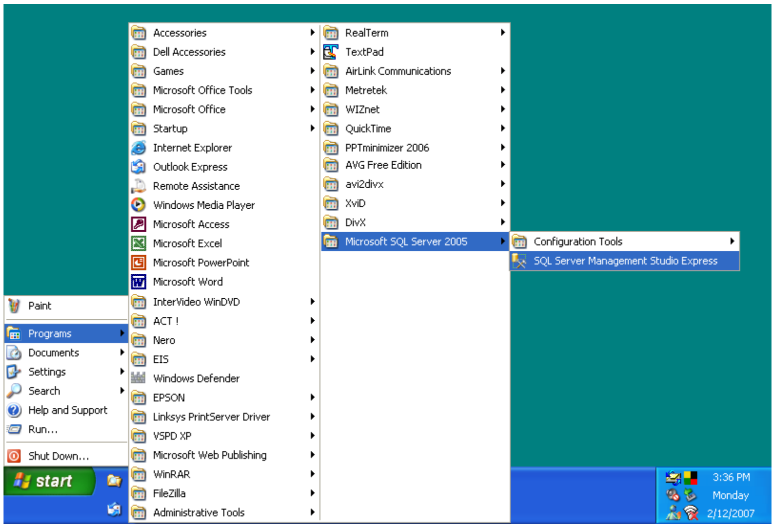
- Click Finish.



Setup of SQL Database Structure for the First Time

1. Load “SQL Server Management Express”

- Start – Programs – Microsoft SQL Server 2005 – SQL Server Management Express



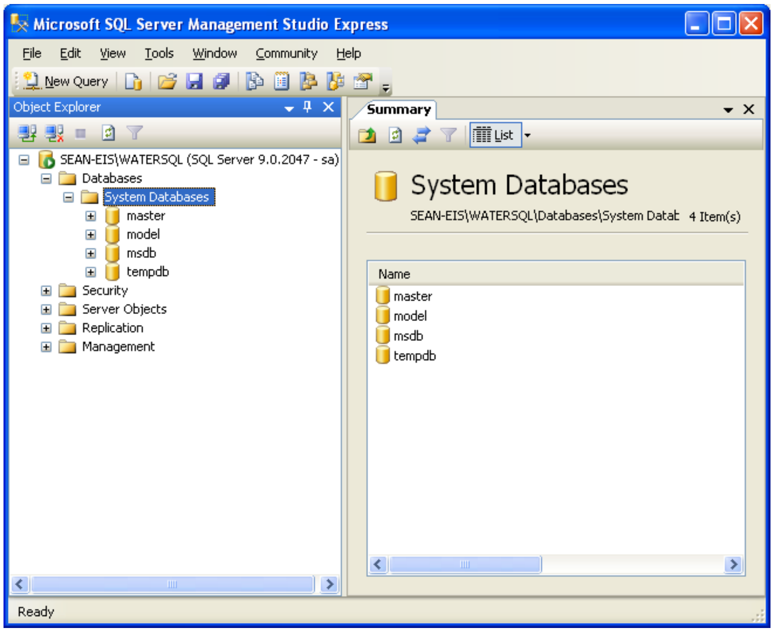
2. Connect to Server

Server Name: COMPUTER\WATERSQL

- Substitute “COMPUTER” with the name of the SQL server
- Authentication: SQL Server Authentication
- Logon: sa
- Password: admin1
- Click Connect.

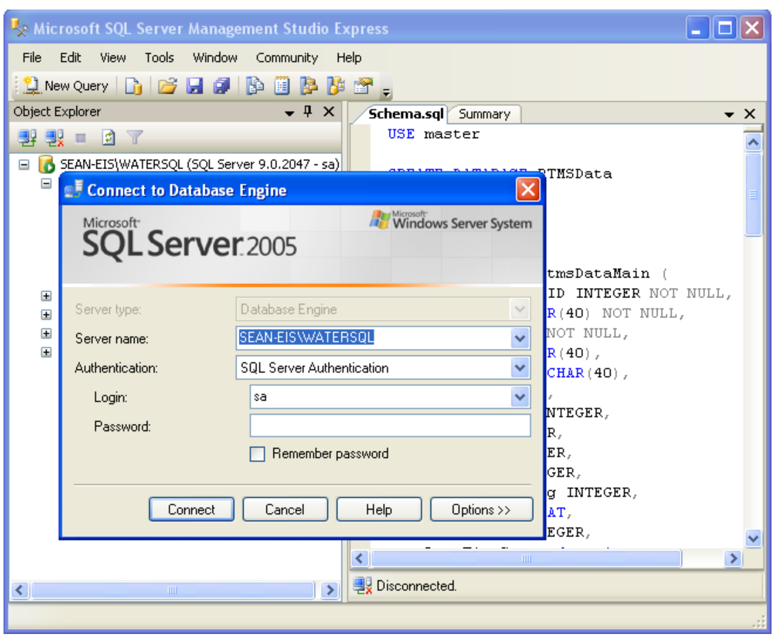
3. SQL Server Management Studio Express Main Screen

- Click File, Open, File
- Find and Select “Schema.sql”
- Open.



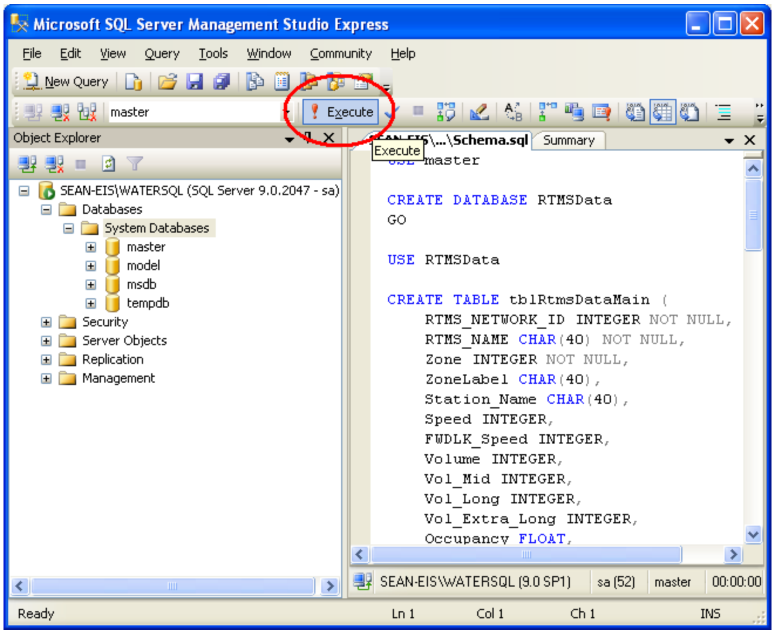
4. Logon to SQL Management Server Express Again

- Logon to server again is required before script can be run.
- Enter password "admin1."
- Click Connect.



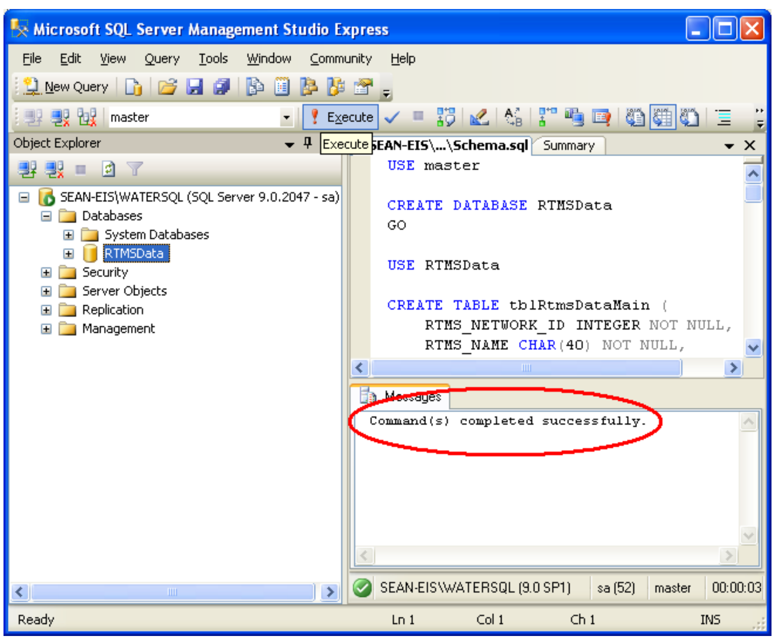
5. Execute Script to Setup Database

- Once script is open, click "Execute" Icon on the task bar.



6. Scripted Executed, RTMSDATA Created

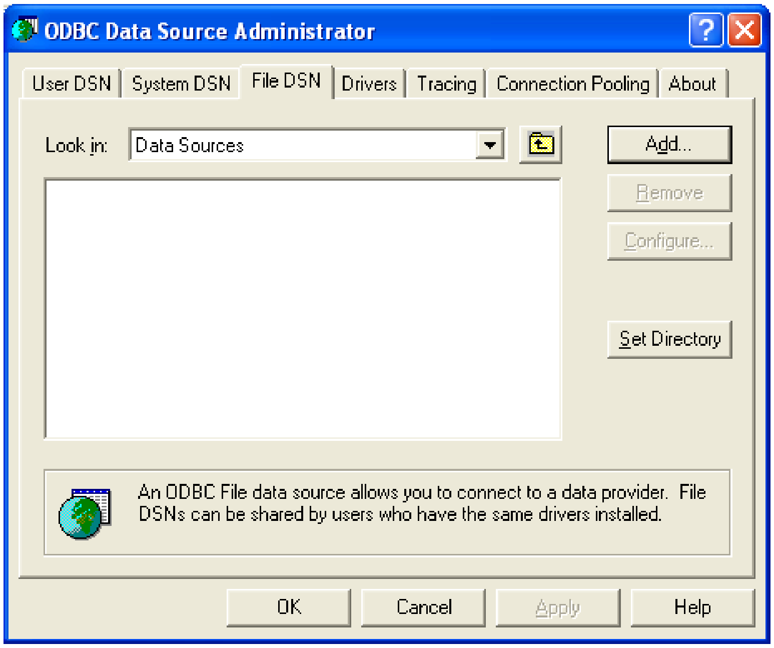
- Once the script has been created, RTMSData should have been successfully created.
- A refresh may be required before the database is seen.



Creating A DSN

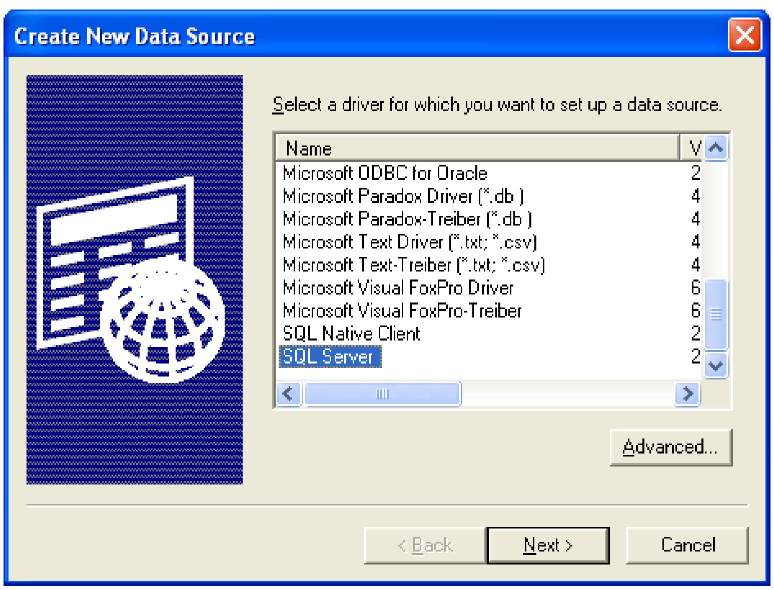
1. Opening DSN Window

- go to: Control Panel – Administrative Tools – Data Sources (ODBC).
- Click “File DSN” Tab and then Click “Add.”



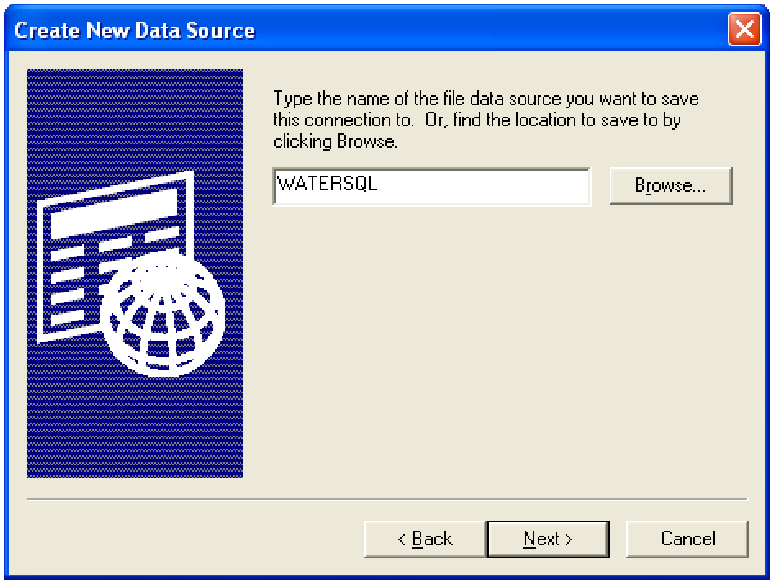
2. Create New Data Source

- Scroll Down to bottom of list and select “SQL Server.”
- Click Next.



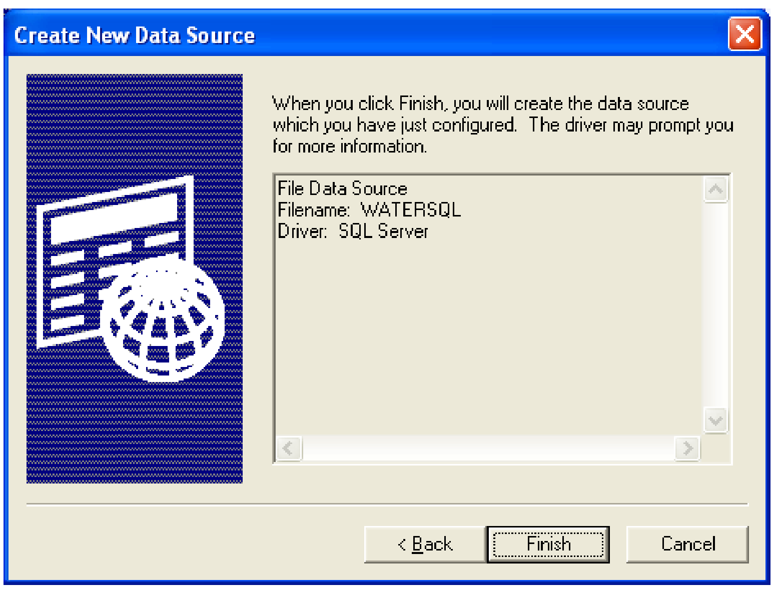
3. Create New Data Source

- Enter the name for the source “WATERSQL.”
- Click Next.



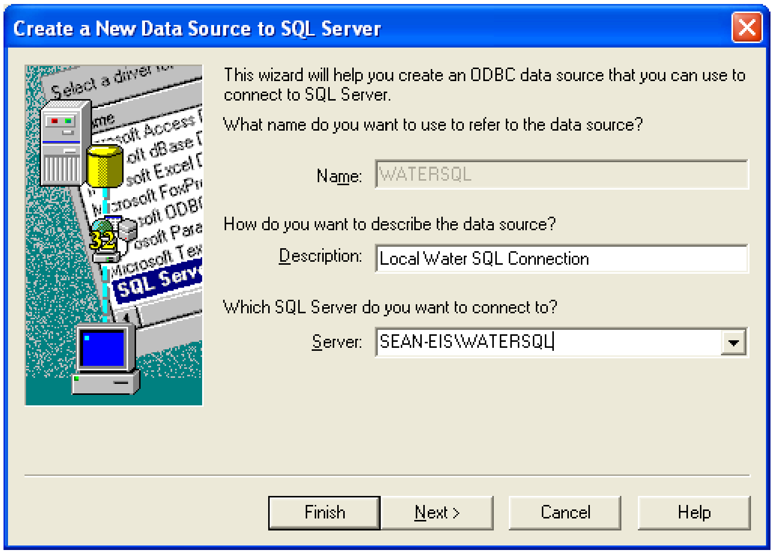
4. Create New Data Source

- Click Finish.



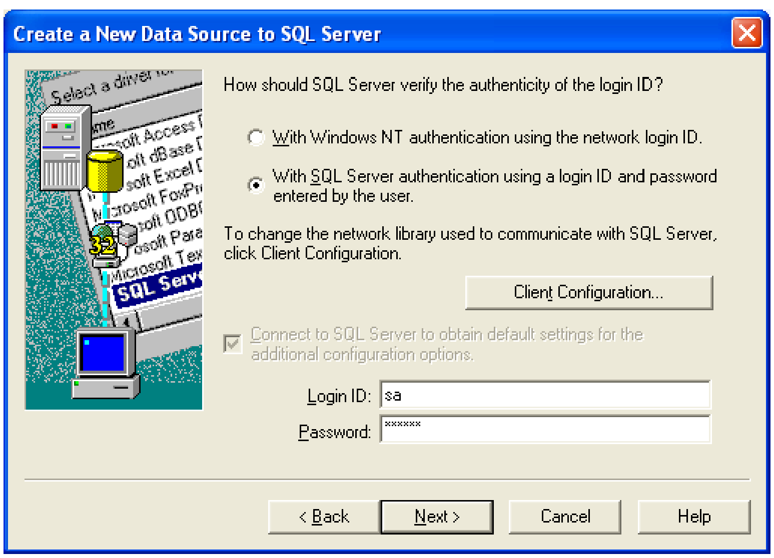
5. Create New Data Source to SQL Server

- Enter in the description.
- Enter in the server name. "SERVER\WATERSQL."
- Substitute "SERVER" with name of server PC.
- Click Next.



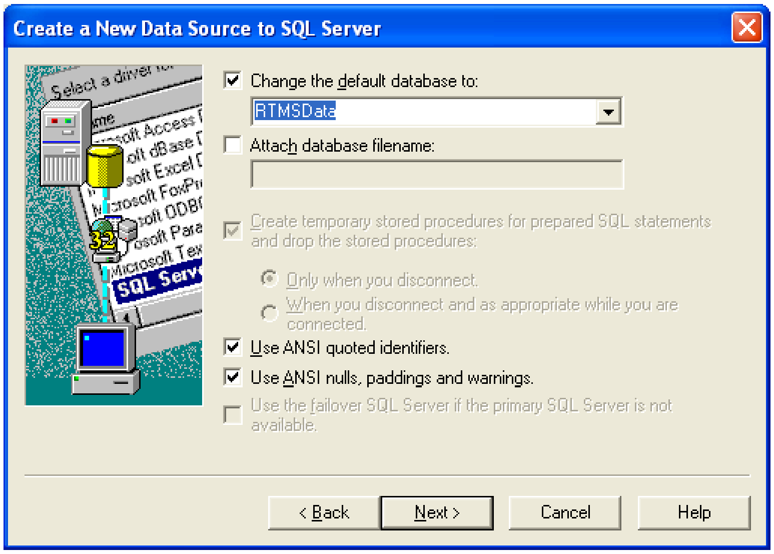
6. Create New Data Source to SQL Server

- Select "SQL Server Authentication"
- Login ID: sa
- Password: admin1
- Click Next.



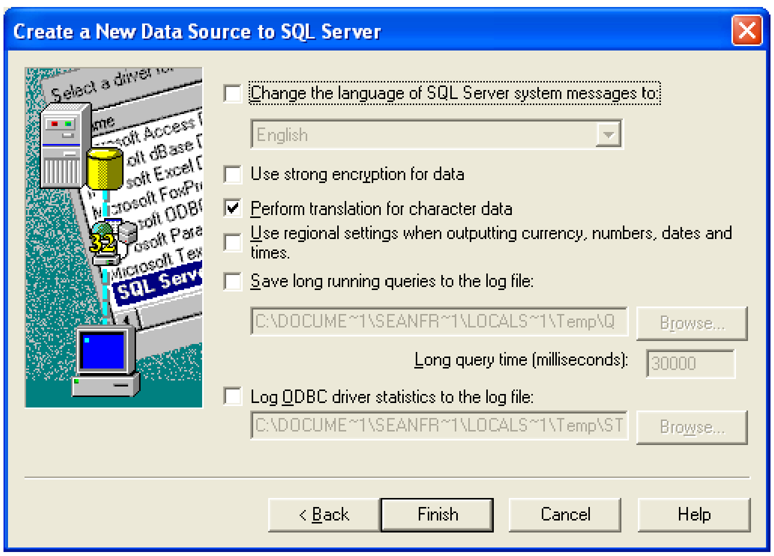
7. Create New Data Source To SQL Server

- Select "Change the default database to."
- Select "RTMSData" from the pull-down.
- Click Next.



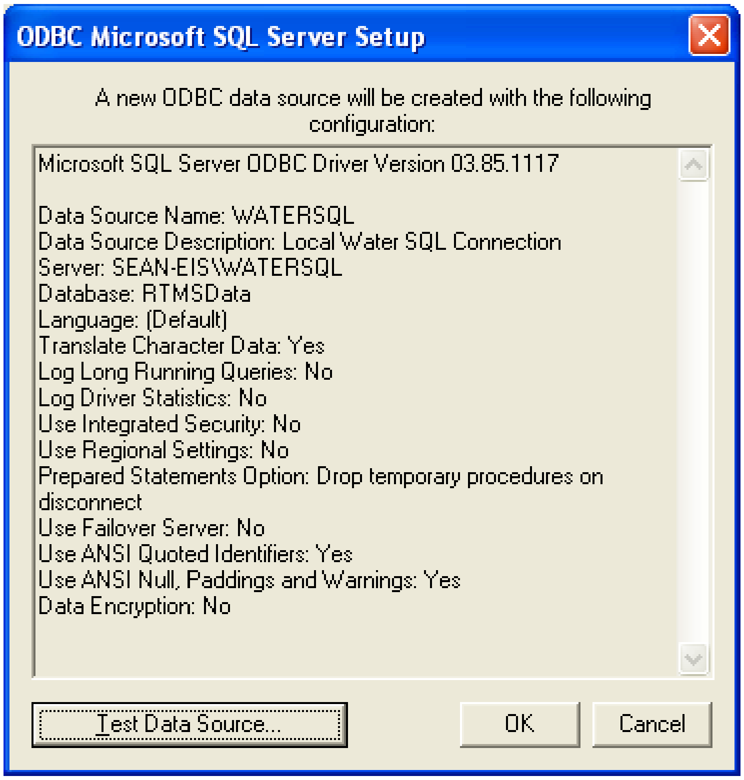
8. Create New Data Source To SQL Server

- Leave defaults, click Finish.



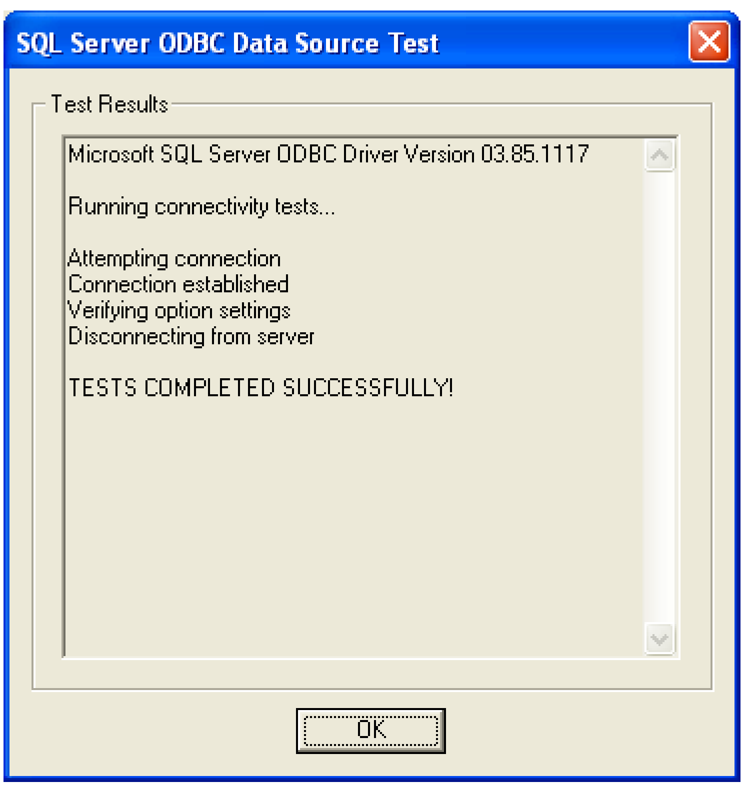
9. Test Data Source

- Click "Test Data Source."



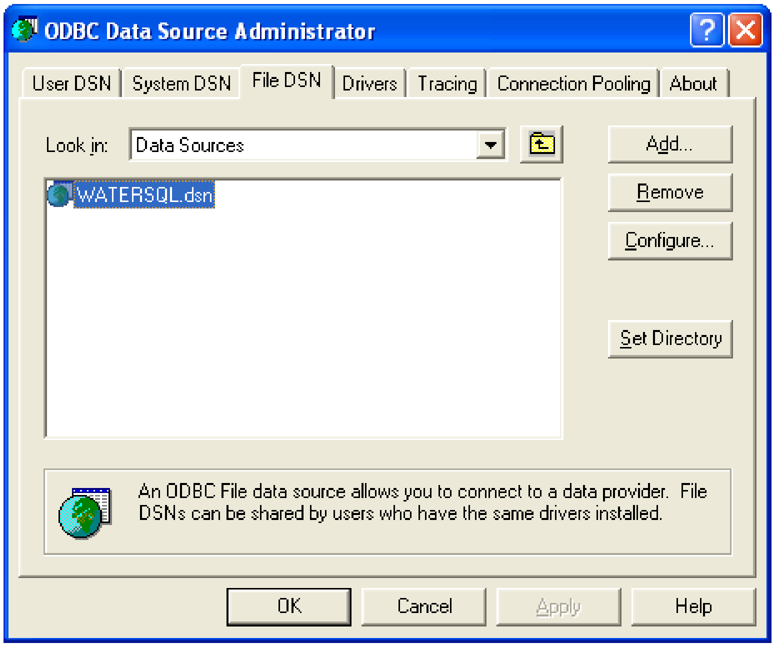
10. Test Data Source

- Ensure test was completed successfully.
- Click OK, then OK.



11. ODBC Source Administrator

- You should now see an entry "WATERSQL.dsn."
- Click OK.

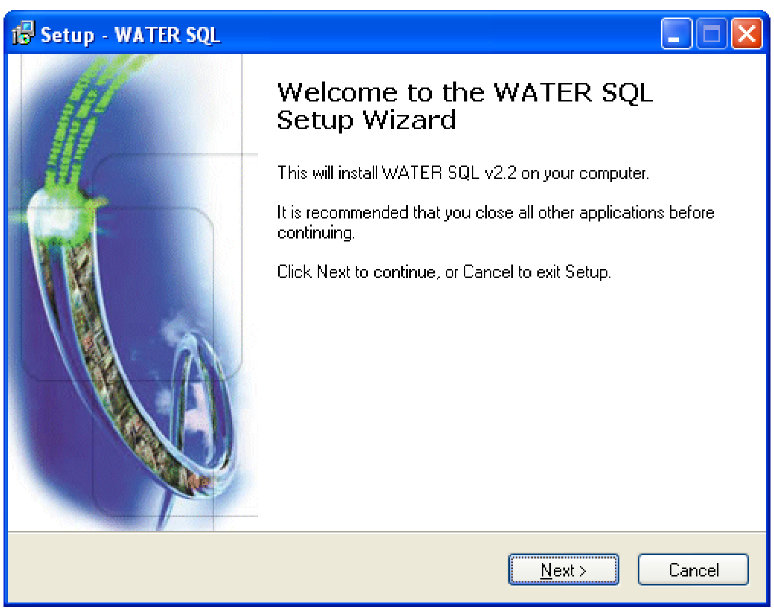


Installing WATER 2.2

Once SQL Server has been installed and a DSN has been created, the following instructions must be followed to install WATER/SQL 2.2.

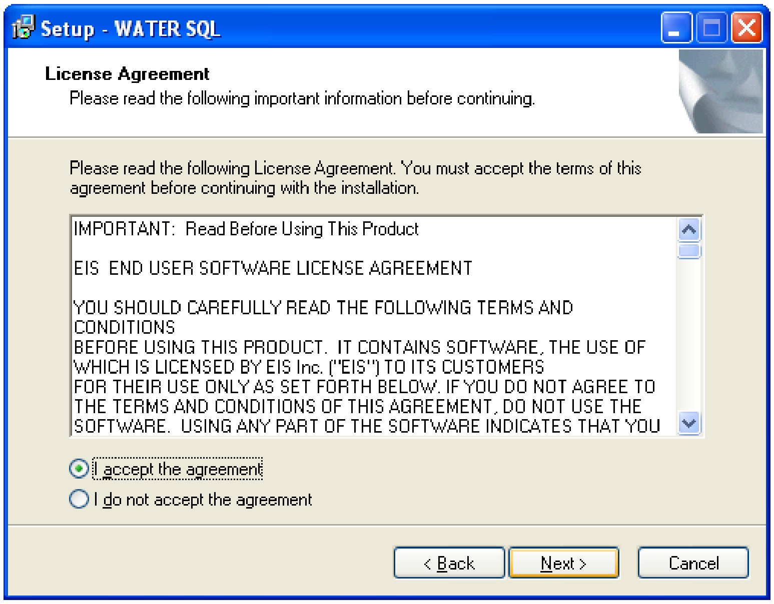
1. Run "WATER_SQL_2_2.exe"

- Click Next.



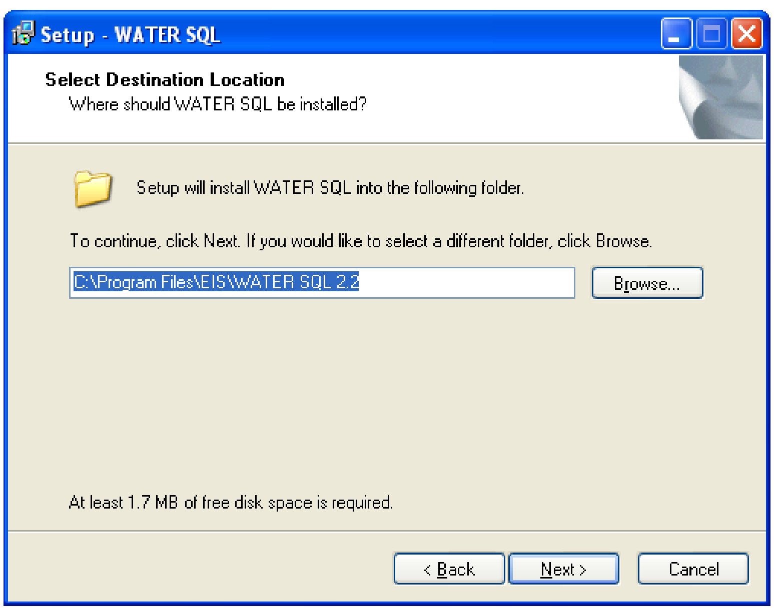
2. License Agreement

- Click "I Accept."
- Click Next.



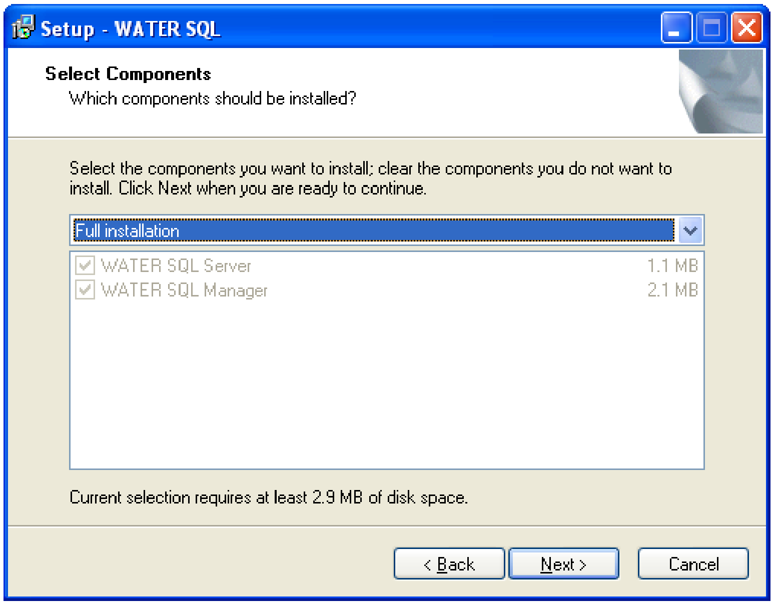
3. Select Destination Location

- Leave the default location as selected by the installer.
- Click Next.



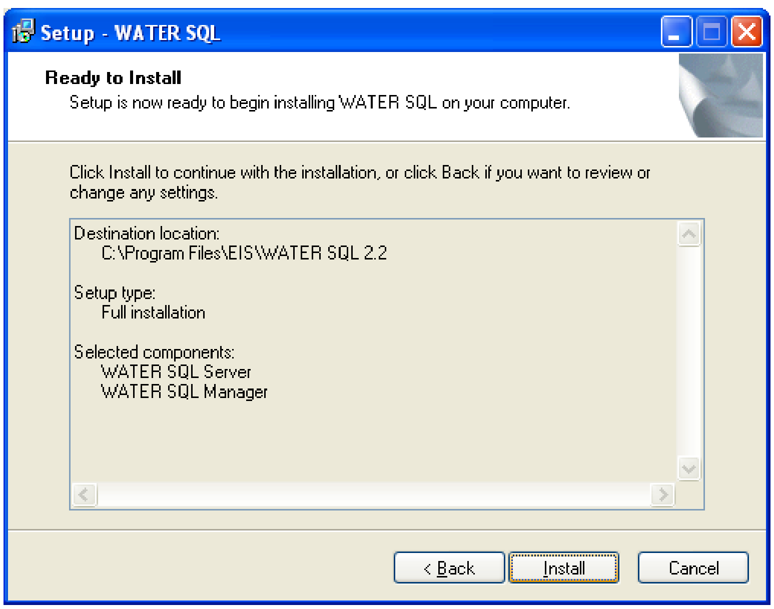
4. Select Components

- Select "Full Installation" from the pull-down menu.
- Click Next.



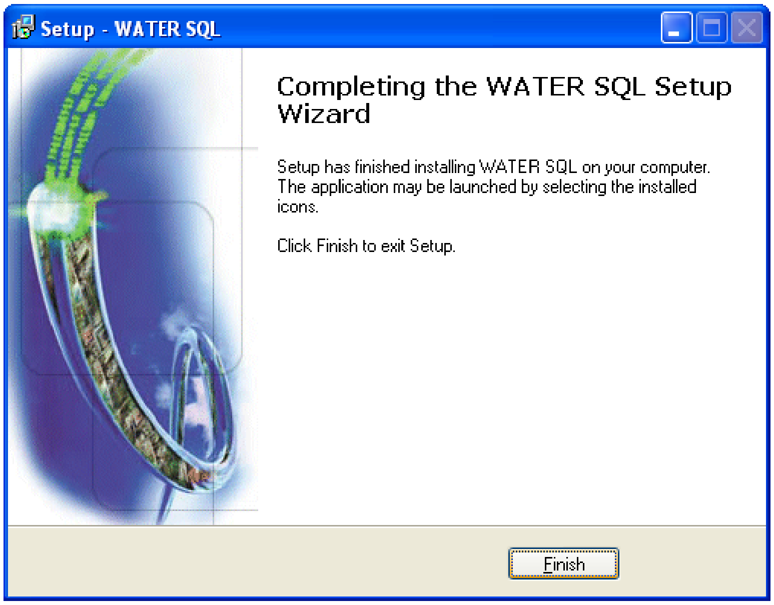
5. Verify Settings Before Installation

- Click Install.



6. Installation Complete

- Installation of the WATER/SQL software is now complete.
- Click Finish.

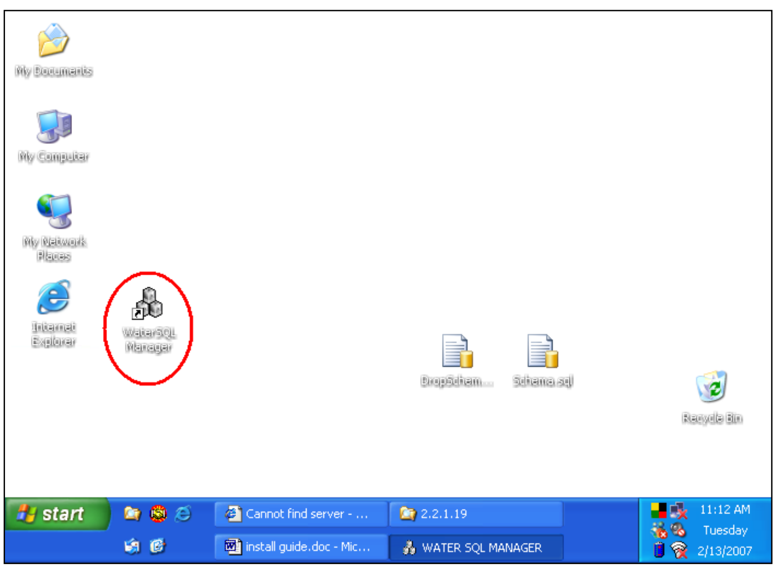


Configuring the WATER/SQL Software

Following the installation of WATER/SQL, the following steps are required to direct WATER to use the DSN connection to the SQL Server previously created and to set it up to start collecting data from RTMS sensors.

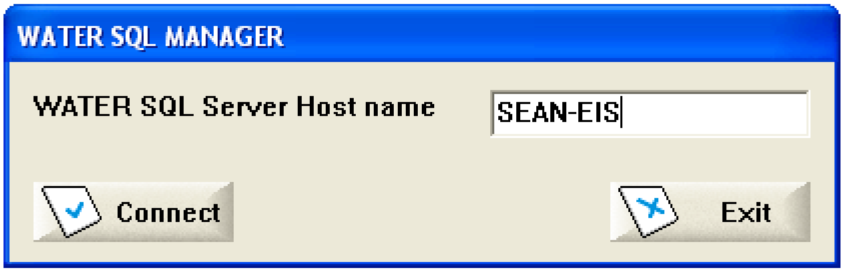
1. Open the WATER/SQL Station Manager.

- Double click on the Station Manager Icon on the Desktop.



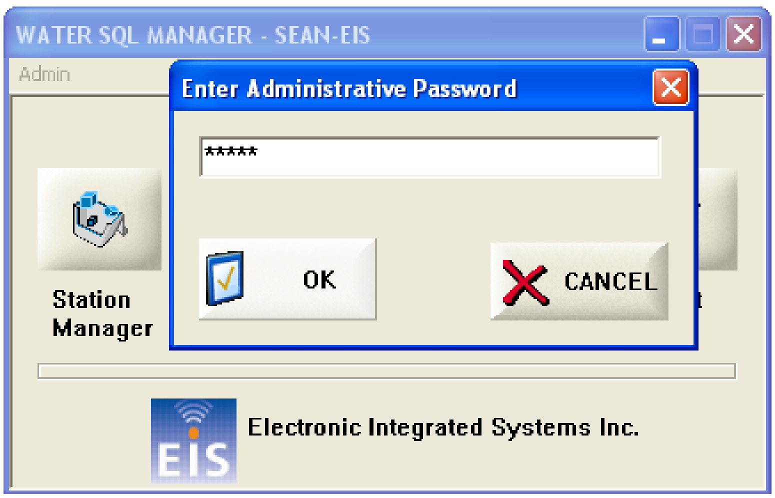
2. Connect to WATER/SQL Server Engine.

- Enter the name of the PC that the WATER/SQL is running on (most likely the same PC that you are currently using).
- Click Connect.



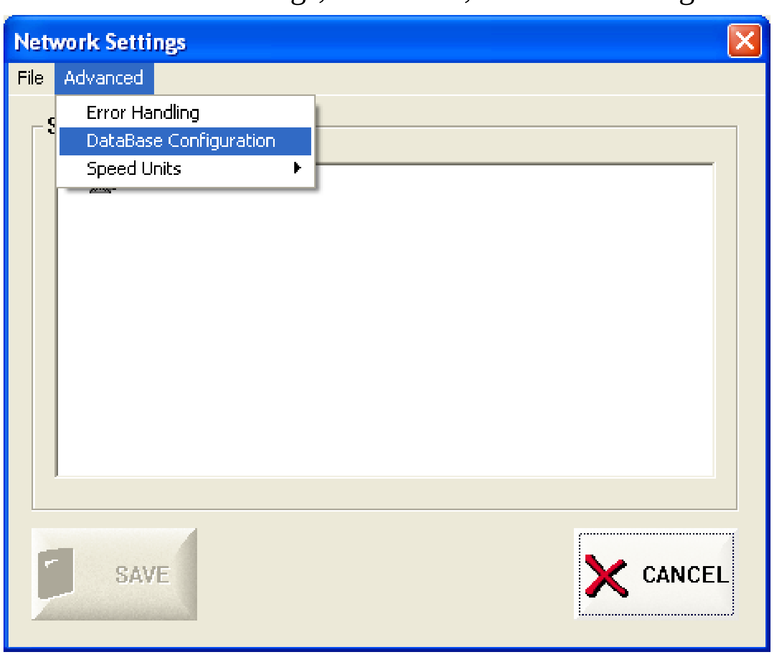
3. Login As Admin

- Click File, Login.
- Enter password “admin.”
- Click OK, then OK.



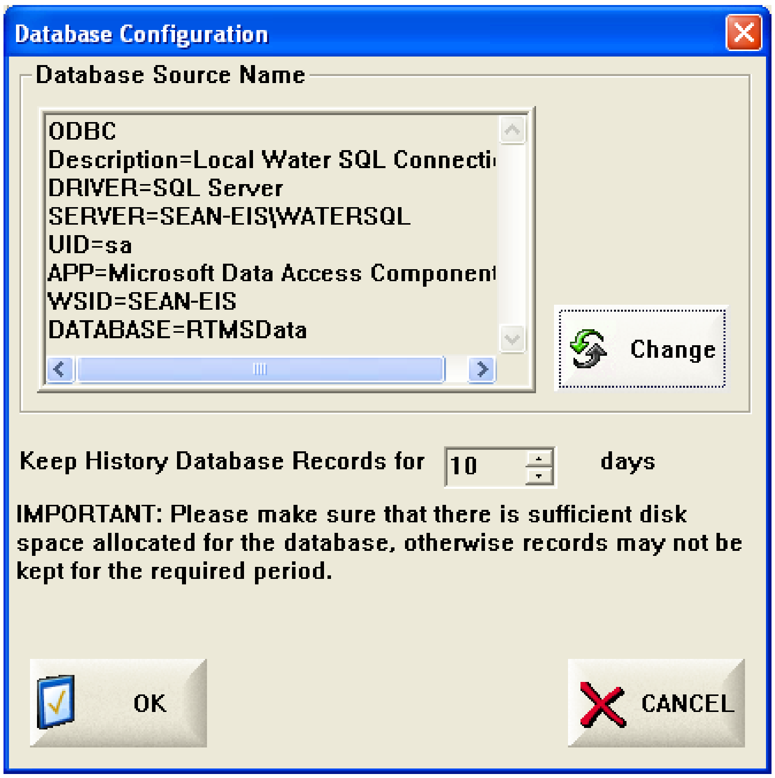
4. Configure Network Settings

- Click Network Settings, Advanced, Database Configuration.



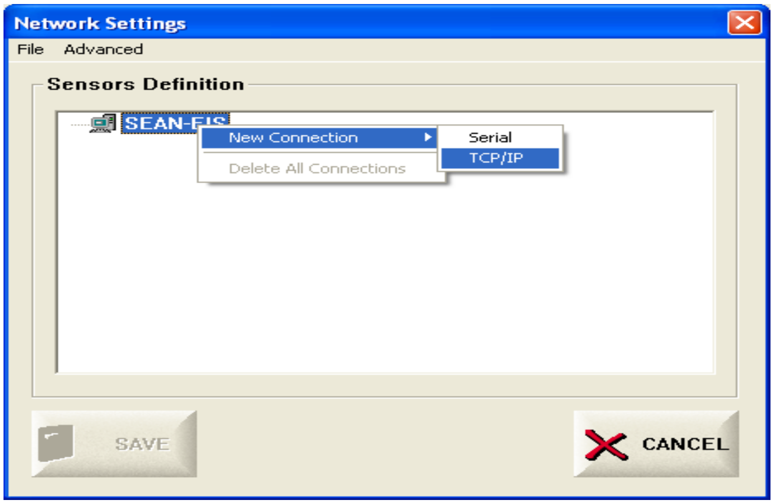
5. Selecting the DSN

- Click Change.
- Click on DSN “WATERSQL.dsn.”
- Click OK.
- Enter User “sa” and password “admin1.”
- Click OK.
- Increase number of days to collect data to 360.
- Click OK.



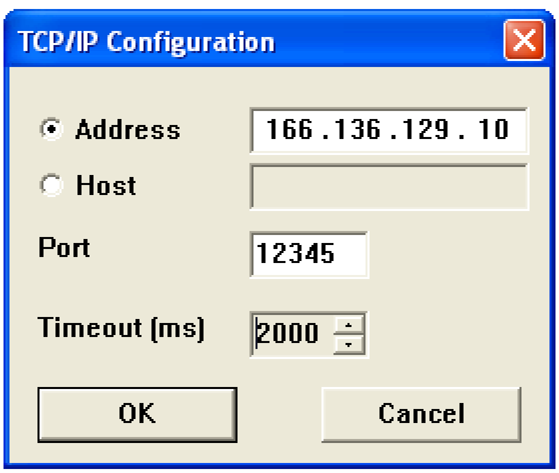
6. Adding a Cellular-IP connected RTMS

- Right Click on Computer Name, Select New Connection, TCP/IP.



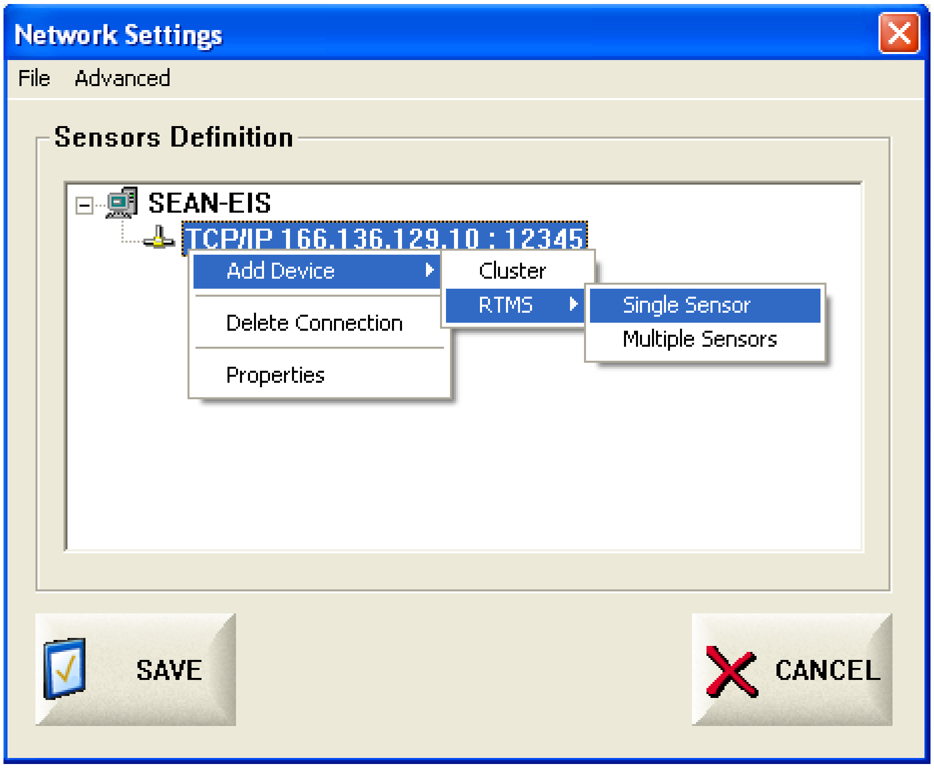
7. Enter the details of the New Connection (Trailer Airlink Modem)

- IP: 166.136.129.10
- Port: 12345
- Timeout: 2000
- Click OK.



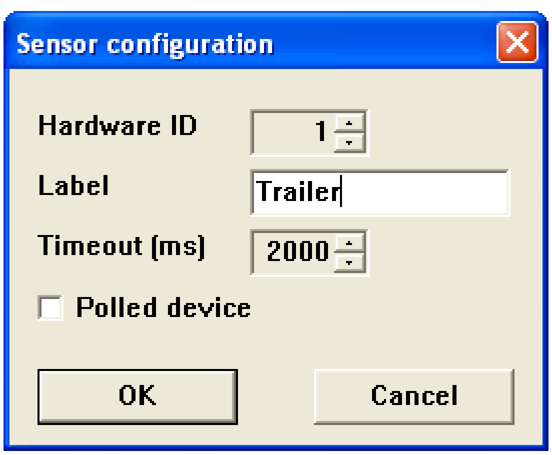
8. Adding a Single Sensor

- Right Click on IP Connection, Add Device, RTMS, Single Sensor.



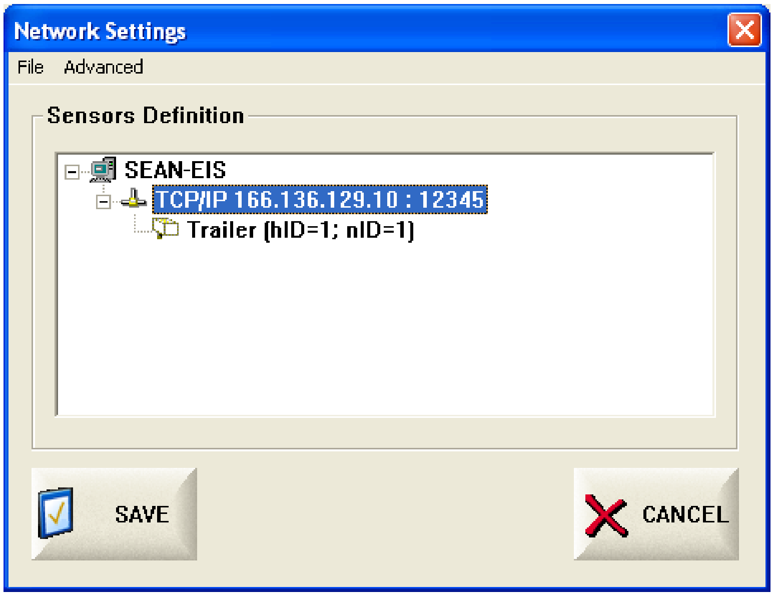
9. Sensor Configuration

- Enter sensor ID: 1 and a label of your choice “Trailer.”
- De-select polled device (This can be changed later if we require that the sensor be polled over IP).
- Click OK.



10. Save Settings

- Setup should look the same as below.
- Click Save.

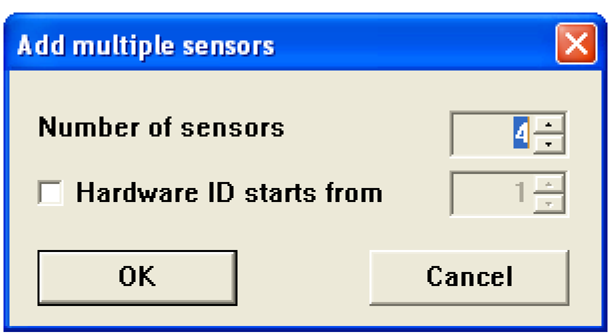


WATER should now be setup to collect data in real-time from this sensor. Data can be accessed in the same manner as it would from any other SQL Database. Some of the off-the-self utilities that may also work are Microsoft Excel, Crystal Reports and Access, to name just a few. For this setup, unless the PC with WATER and SQL is up and running, no data will be collected locally at the site. The PC must be turned on and connected to the internet for data collection to take place.

Additional Notes and Instructions for the Atchafalaya Bridge Setup:

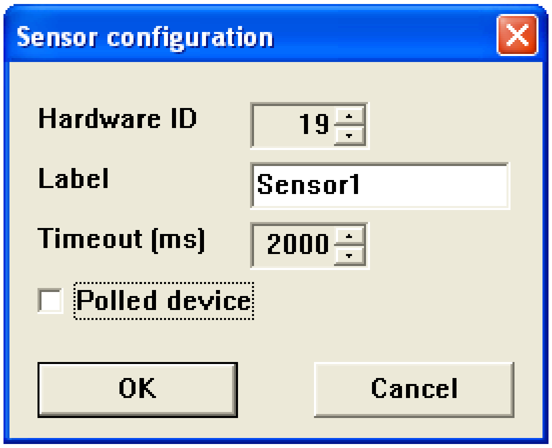
Continuing from step 8, instead of selecting "Single Sensor," the "Multiple Sensors" option must be selected.

- Enter the number of sensors which in this case would be 4 since only 4 of them are currently talking back to the master at the tower.
- Deselect "Hardware ID Starts from.
- Click OK.

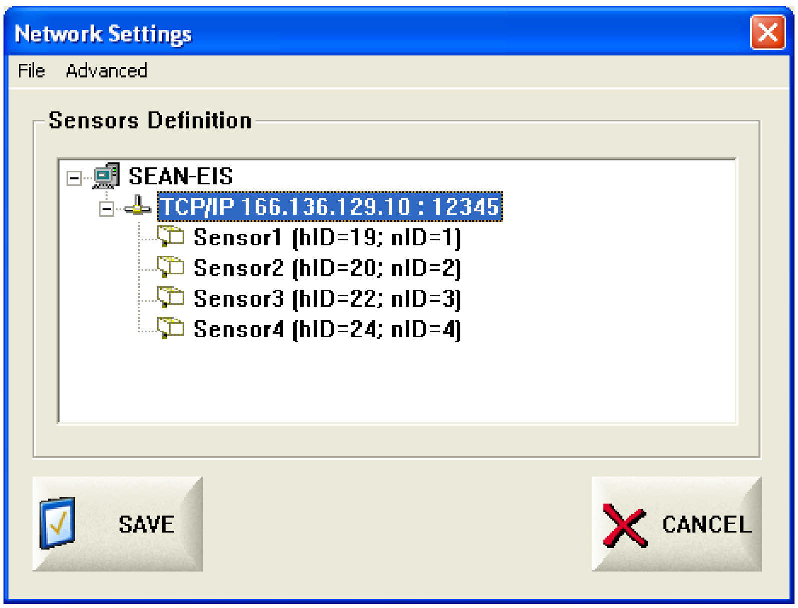


- Enter each Hardware ID and Sensor Label.
- Deselect "Polled device" (The cluster is doing the polling for us and simply forwarding the data to the WATER/SQL Engine. To the WATER Engine, the Cluster Controller is invisible and it thinks that the RTMS sensors are operating in Stat mode.)

- Click OK.



The Final Settings should look similar to the screenshot below (Note, HW IDs may be different):



This concludes the setup of the WATER System for real-time data collection.

APPENDIX B

Sample of Survey Cover Letter

Dear Sir or Madam,

A research team from Louisiana State University and the University of Louisiana at Lafayette is conducting a research study to evaluate the traffic safety impact of restricting trucks to the right lane and reducing their speed to 55 mph on Interstate 10 over the Atchafalaya Basin (Please see the map attached). As part of the study, a survey is being administered to solicit feedback from the truck companies and drivers on the implemented policies.

More specifically, this survey is intended for truck drivers who have traveled on this section at least once since September 2003, when new policies took place. Please forward this survey to as many drivers as possible who might fit this criterion and encourage them to respond to this short survey. The estimated time to complete this survey is 5 minutes. The survey is conducted for research purpose only, and therefore, the survey results will be anonymous.

Attached are five copies of the survey questionnaire and five copies of self-addressed and postage paid "business reply mail" envelopes. Please complete and return the survey form; your prompt reply will be greatly appreciated. Should you need additional survey forms, please feel free to make copies of the enclosed survey form.

If you have any questions, please contact Dr. Sherif Ishak or Dr. Brian Wolshon at Louisiana State University, Department of Civil and Environmental Engineering.

Thank you for your cooperation and the valuable information you are providing in this survey.

Sincerely,

Sherif Ishak, Ph.D.
Department of Civil and Environmental Engineering
Louisiana State University
3418A CEBA Building
Baton Rouge, LA 70803
Phone: (225) 578-8652
Email: sishak@lsu.edu

Brian Wolshon, Ph.D.
Department of Civil and Environmental Engineering
Louisiana State University
3505B CEBA Building
Baton Rouge, LA 70803-6405
Phone: (225) 578-8652
Email: brian@rsip.lsu.edu

APPENDIX C

Sample of Survey Results

PART 1: GENERAL INFORMATION

1. How many years did you work as a truck driver?

☐ Less than 1 ☐ 1 to 5 ☐ 6 to 10 ☐ 11 to 15 ☐ 16 to 20 ☑ More than 20

2. What is the type of vehicle you are currently operating?

☑ Tractor Semitrailer ☐ Straight Truck ☐ Other:

PART 2: ATCHAFALAYA SWAMP FREEWAY

3. Since September 2003, how many times have you traveled on the Atchafalaya section of Interstate 10? Approx. 480

Note: This elevated roadway is located between Lafayette and Baton Rouge. Going eastbound, it starts near Henderson, and ends near Ramah. Please see the map attached.

PART 3: POLICY

4. Are you aware of the different speed limits for trucks and cars (55 mph for trucks and 60 mph for cars) at this location?

☑ Yes ☐ No

5. Are you aware of the policy that is restricting trucks to the right lane at this location?

☑ Yes ☐ No

PART 4: SAFETY

6. Do you think the current speed limits might improve the safety at this location?

☐ Yes ☑ No ☐ Do Not Know

If yes, to what degree? ☐ Significantly ☐ Average ☐ Not Significantly

7. Do you think the current policy that is restricting trucks to the right lane might improve the safety?

☐ Yes ☑ No ☐ Do Not Know

If yes, to what degree? ☐ Significantly ☐ Average ☐ Not Significantly

PART 5: WARNING AND ENFORCEMENT

8. Do you believe that there is sufficient warning about the speed limits and the lane restriction at this location?

☑ Yes ☐ No

9. Do you believe that the legibility of the warning signs is adequate?

☑ Yes ☐ No

10. Have you ever received citation for violation of the speed limit at this location since September 2003

☐ Yes ☑ No If yes, how many times?__________

11. Have you ever received citation for violation of the lane restriction at this location since September 2003?

☐ Yes ☑ No If yes, how many times?__________

PART 6: LANE CHANGING

12. What are the two primary reasons you might need to change lanes when driving this road segment?

For Emergency Vehicles

For Stalled or Broke Vehicles

PART 7: FUTURE STRATEGIES

13. Which of the actions below do you think should be taken by the Louisiana Department of Transportation and Development? (you can choose more than one)

Strategies Relating to Speed

- [ ] Keep the 55 mph speed limit for trucks in force
- [ ] Keep the 60 mph speed limit for cars in force
- [ ] Keep the lane restriction in force
- [x] Change the speed limit for trucks to 60 or Same As Cars mph
- [x] Change the speed limit for cars to 60 or Same As Trucks mph
- [ ] Set different speed limits for left and right lanes: _____ mph for left lane, _____ mph for right lane
- [ ] Reduce the speed limit for all vehicles during the peak hours
- [x] Place a mechanism on the section that detects an incident and warns the drivers before they approach the scene
- [ ] Place a mechanism that informs a driver of his/her cruising speed versus the posted speed limit
- [ ] Double the fines for speed and lane violations

Lane Restriction Strategies

- [ ] Restrict trucks to the left lane and allow them to change lanes at exits
- [ ] Restrict cars to the left lane and allow them to change lanes at exits
- [ ] Restrict cars to the right lane
- [ ] Restrict a truck to the lane that it was in at the beginning of the section
- [ ] Restrict a car to the lane that it was in at the beginning of the section
- [x] Do not implement any kind of restriction for trucks
- [ ] Separate left lane from the right lane using barriers

Roadway Lighting Strategies

- [x] Improve the lighting along the section

Enforcement Strategies

- [ ] Increase the number of law enforcement patrols

Other Strategies (Please Specify)

- [x] Make The Speed Limit The Same for Both Cars & Trucks Without Lane Restrictions

14. How would this strategy benefit to the traffic safety and operations on this segment, the trucking industry, and the roadway pavement?

I think Everyone Traveling at The Same Speed Is Safer

PART 8: ADDITIONAL INFORMATION

15. What else would you like to mention about the lane restriction and speed limit policy for trucks at this location?

APPENDIX D

Supplementary Statistics

With the available crash data for 2007 and 2008, the following charts are made:

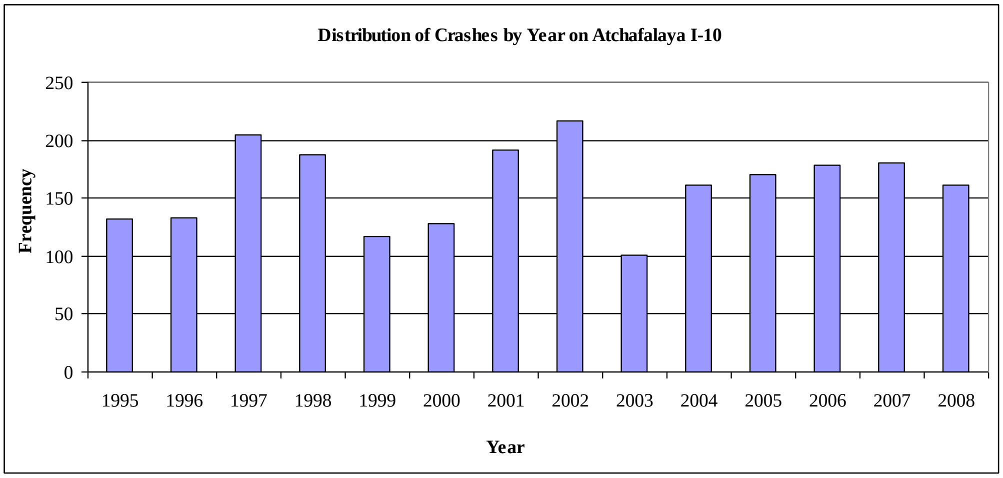


Figure 163
Total crashes by year

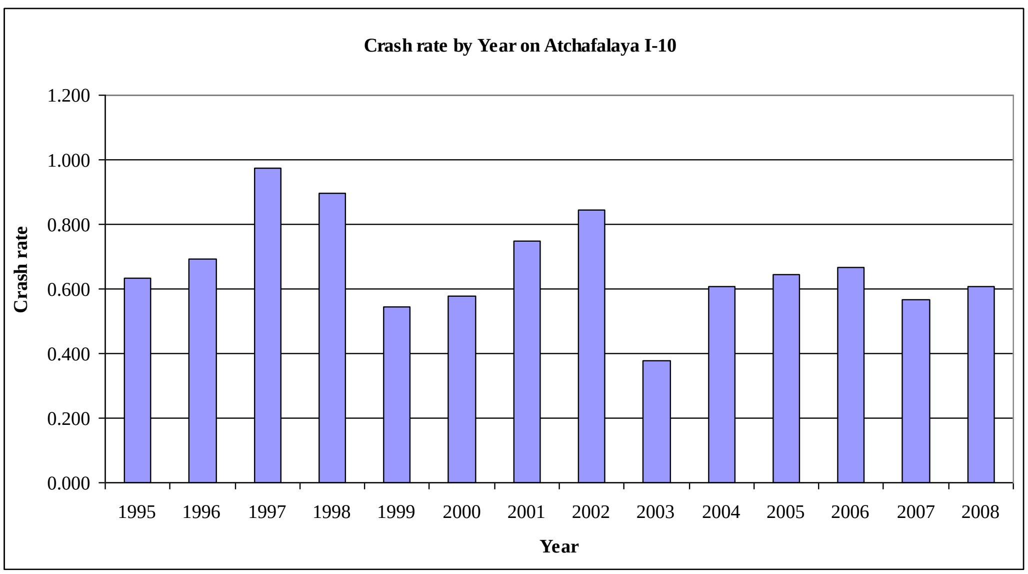


Figure 164
Total crashes rate by year

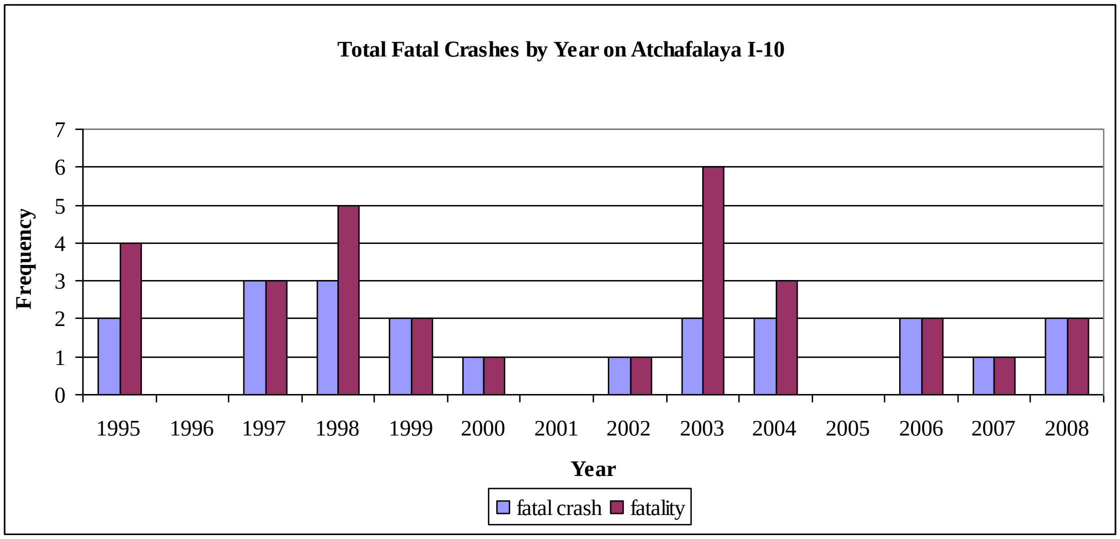


Figure 165
Total fatal crashes by year

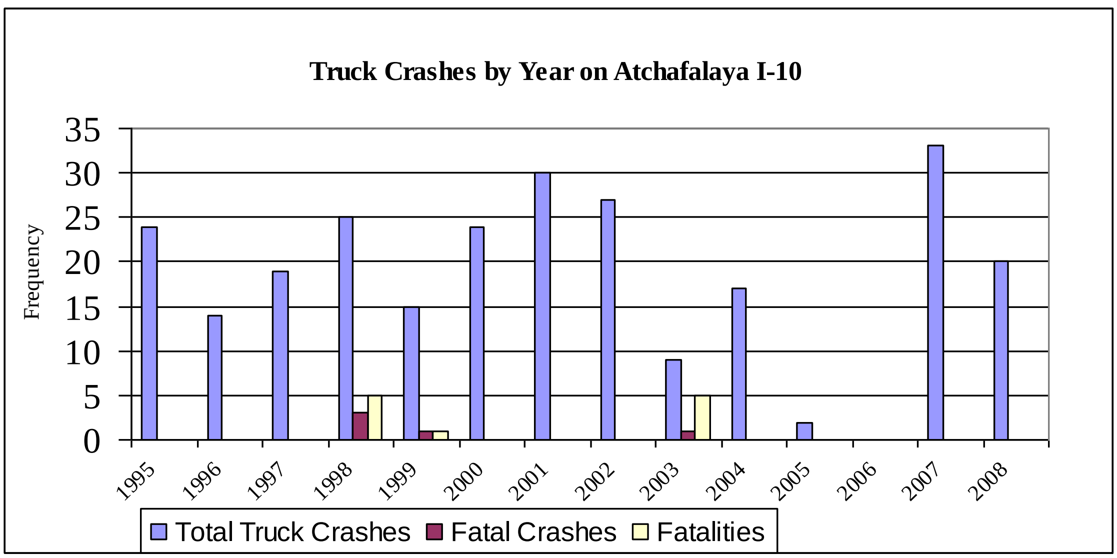


Figure 166
Total truck crashes by year

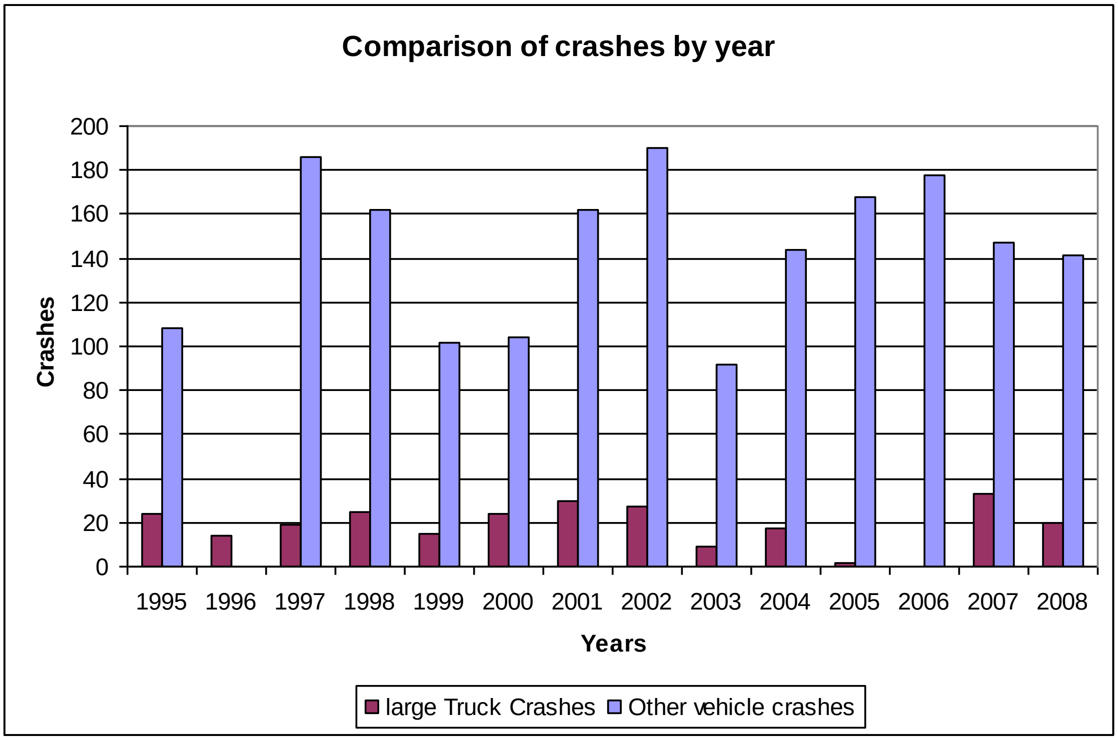


Figure 167
Comparison of crashes by vehicle

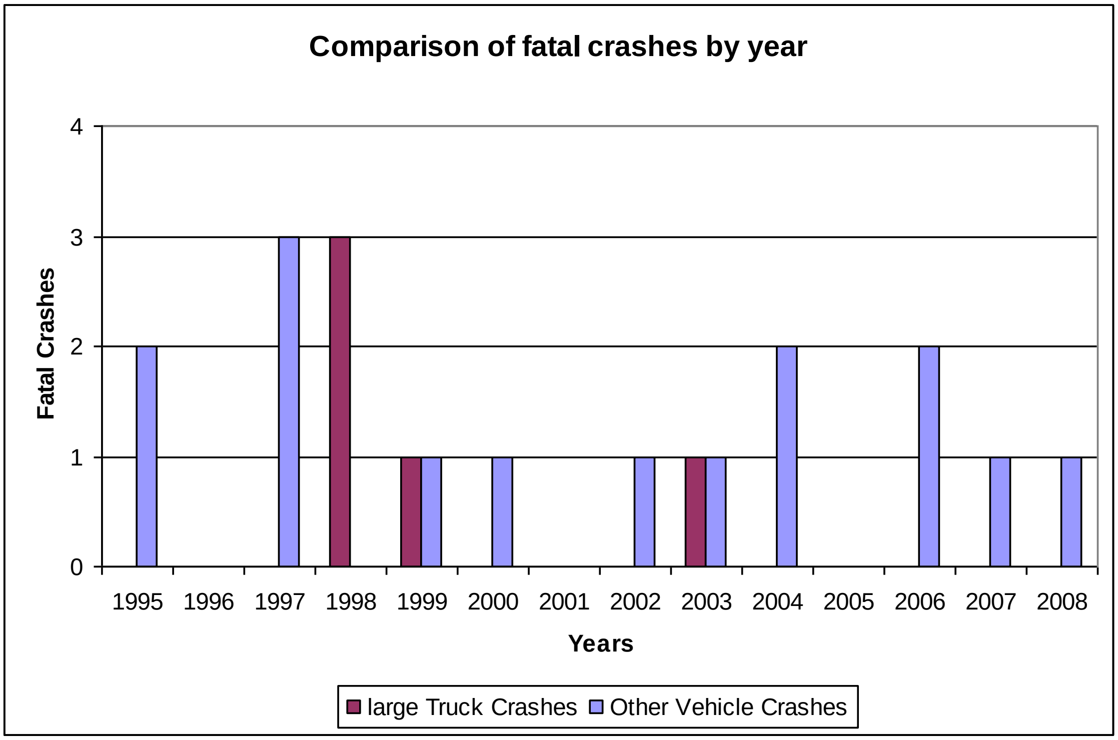


Figure 168
Comparison of fatal crashes by vehicle

Summary

1. While the total number of crashes remains stable or approximately at the same level in 2007 and 2008, the truck crashes increased in both years compared to the numbers in 2004, 2005, and 2006 (the "after" time period).
2. While there were one fatal crash in 2007 and two in 2008, there was no fatal truck crashes in both years.