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Steer It and Clear It: Effectiveness of Quick Clearance Legislation

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STEER IT AND CLEAR IT: EFFECTIVENESS OF QUICK CLEARANCE LEGISLATION

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ABSTRACT

Innovative incident management strategies have been sought by transportation professionals to minimize the impacts of incidents on traffic operation and safety. Some current quick clearance strategies such as "Steer It and Clear It" legislation in South Carolina, which requires driver(s) of involved vehicle(s) in a minor incident to move vehicles promptly from the traveled roadway prior to the arrival of the first responders, can potentially reduce the duration of an incident. The research detailed in this paper endeavored to measure the benefit of the Steer It and Clear It law on a section of I-85 in South Carolina. A simulation analysis using the microscopic traffic simulation platform PARAMICS suggested that the total traffic delay can be reduced for minor incidents with one lane blocked as a result of the reduced incident clearance time that Steer It and Clear It legislation can provide. This reduced delay, as well as reduced emissions and fuel consumption, resulted in an average cost savings of $872 per incident, which is significant when considering the number of minor incidents occurring on a daily basis in large metropolitan areas. Besides affecting congestion and its associated problems, reducing incident duration through the Steer It and Clear It law can also improve the safety of both road users and incident response personnel.

DEDICATION

I would like to dedicate this thesis to all the friends and family who have been so supportive of me throughout my life, and specifically in the past year. Thanks especially to Mom and Dad and all my brothers and sisters who listened so patiently when I complained about my work, and who were such encouragements, both mentally and spiritually. I also want to thank Storm, Jewell and Anna Ruth for being the sweetest nieces: I love you. I give God any glory that this humble paper could possibly gain, and thank Him for being my sustenance and my satisfaction at all times. “My sinful self: my only shame, my glory: all the Cross!”

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CHAPTER ONE
INTRODUCTION

Problem Statement

Traffic incidents, including major and minor crashes as well as disabled vehicles, are estimated to be the cause of 52 to 58% of all traffic congestion (*1*). This congestion is also known as nonrecurring congestion, which signifies its unexpected nature. Delay that is due to traffic incidents also affects travel time reliability, which is highly valuable to both motorists and the community. Unexpected delay therefore comes at a much higher price to both of these groups, when compared to recurring traffic delays caused by regular peak hour traffic loads. Incidents cost the nation at least $230 billion in congestion costs (*2*). Congestion costs include property damage, present and future medical costs, lost workplace and household productivity, legal and insurance expenses, and travel delay costs.

Incident delay can bring about many negative outcomes in terms of lost productivity, increased fuel consumption and emissions, diminished quality of life, and numerous other consequences. In addition, crashes represent a significant risk on high-speed freeway facilities. Such risks involve secondary crashes, or subsequent incidents due to delayed vehicles affected by the previous (primary) incident, and "struck-by" incidents, in which emergency responders are hit by other drivers.

Background of Incident Delay

Incident duration is comprised of four distinct phases: detection and verification, response, clearance, and recovery. When an incident occurs, each of these phases is crucial in determining the effects of that incident on traffic. Once the detection and verification stage is complete and response teams have arrived on the scene, responders must act quickly to ensure that vehicular traffic is returned to normal operating conditions as soon as possible. In order to reduce the duration of the incident and thus minimize traffic delays, strategies must be examined to shorten the amount of time spent in each of these phases. Incident management programs designed to minimize all four stages of incident duration have been initiated in most major urban areas in the United States. Such programs include traffic cameras, freeway service patrols, and other detection methods, as well as multi-agency response programs to allow for traffic management, vehicle and cargo removal, and traveler information dissemination. Incident clearance strategies must consider efficiency as well as the safety of victims, road users, and emergency responders on the incident scene.

Due to the array of concerns associated with incidents and incident delay, transportation authorities have begun studying methods to clear incidents as quickly as possible, with the intent to relieve the amount of heavy traffic volume that results from reduced roadway capacity when travel lanes are blocked. Quick clearance legislation is one of these methods, and it addresses the issues of incident delay beginning at the time of the incident.

Quick Clearance Legislation

Quick clearance of incidents is an issue of interest to many state Departments of Transportation concerned with determining the best practices that will produce minimal delay. One definition of quick clearance is "the practice of rapidly and safely removing temporary obstructions from the roadway" (*3*). These "obstructions" can include the vehicles involved in an incident as well as spilled cargo from commercial vehicles. Quick clearance practices can be enacted by legislation or similar policies to both protect incident responders as well as enforce driver involvement in assisting with incident clearance. While surveys of agencies nationwide have determined that most states have some version of quick clearance legislation (*3*), the question of their effectiveness is a lesser-known dynamic, due to lack of research in this area.

Many states have recently focused on passing and enforcing laws that, in the event of an incident, require prompt clearance action whether by the driver of the vehicle(s) involved or by arriving law enforcement personnel. The National Cooperative Highway Research Program (NCHRP) summarizes the different types of legislation into four categories: driver stop laws, driver removal laws, authority removal laws, and authority tow laws (*3*). All quick clearance legislation has the goal of removing obstacles to this prompt clearance, which might include lengthy crash investigations, unknown incident conditions leading to improper response actions, and uncertainty of procedures to follow in the event of an incident. By documenting policies that streamline the clearance process, all involved personnel can better manage incidents that affect roadway capacity. Quick clearance legislation can also help improve safety to drivers and responding personnel by reducing the time that the incident affects traffic, thereby minimizing traffic delay.

Authority removal and tow laws put responsibility on the response personnel to move affected vehicles and cargo out of the roadway as soon as possible. Often, site investigations result in increased incident clearance times, because law enforcement and the vehicles involved need to determine the cause of the incident. Other causes of delayed incident clearance when freight is involved can include towing of heavy vehicles, as well as spill and cargo cleanup. Though many commercial vehicle owners have historically been concerned with cargo removal because owners want to ensure that the material is handled with care if it is salvageable, this legislation allows transportation authorities to clean up such spills before the owner has examined the material, without threat of repercussion.

Driver stop and driver removal laws both place responsibility on the driver of the vehicle involved in an incident. The driver stop law requires that in the event of an incident, the driver must stop the vehicle at or as close as possible to the incident scene. These laws are already present in most states, with the intent of expediting the incident investigation and clearance process once the highway authority arrives on the scene. Driver removal laws, often called "Move-It" or "Steer It, Clear It" laws (*4*), require drivers to immediately move vehicles with only minor damage out of the traveled roadway lanes prior to the arrival of first responders. This type of law allows for the shortest incident duration in cases of minor crashes, because the detection and verification stage is minimized, and may even be omitted in many situations. The response stage is also not a factor for travel lane blockage; because the clearance could be performed before the response personnel arrive. This research principally concentrates on the driver removal law recently enacted in South Carolina, also called "Steer It and Clear It," which applies to crashes on highway facilities in South Carolina.

Automobile crashes resulting in property damage only, with no serious injuries or fatalities, made up 69.3% of the 6.2 million crashes on America's roadways in 2004 (*5*). This high rate of occurrence suggests that driver removal legislation can have a significant effect on total traffic delays when put into practice for both minor incidents and disabled vehicles.

The success of quick clearance policies and legislation such as South Carolina's "Steer It and Clear It" law will ultimately depend not only on the benefits this system can potentially offer, but also on the traveling public who should be practicing such measures. This will require communication to the public on the existence of the policy, and information on how and when to exercise it. Since South Carolina's law is relatively new, for example, many motorists may not be aware of it, and therefore may not apply the driver removal practice. Therefore, a full evaluation of the benefits of the legislation must also take into account the costs to transportation authorities on conveying the information to drivers.

Research Objective

The objective of this study was to evaluate the effectiveness of the "Steer It and Clear It" legislation by reporting the change in network delay that can result from implementation of this law. Reduced incident delay can positively impact both drivers and the entire community. Making travel time more reliable is a significant concern for policymakers, transportation agencies, and road users, as well as a very important issue for manufacturing and industrial businesses. Reducing variability of travel times by reducing the factors that cause extended nonrecurring delay is an important aspect of quick clearance legislation.

Traffic congestion's impacts on emissions and fuel consumption is another major issue that can be addressed by quick clearance legislation. Incident-related congestion causes "stop-and-go" traffic, which has been shown to produce more harmful emissions and burn more excess fuel overall than traffic moving at steady speeds. Reducing the amount of traffic congestion can provide significant benefit to the environment, which contributes to the health of the entire community.

This study involved using PARAMICS, a microscopic traffic simulation software package to measure the law's effectiveness. PARAMICS allows for customized user programs that can be manipulated to show specific measures of effectiveness, such as delay, emissions, and fuel consumption, which are important parameters when considering the impacts of reduced incident durations produced by quick clearance legislation.

The research presented in this thesis demonstrates the effects of quick clearance legislation on incident delay and its associated costs, which can include productivity benefits, secondary crash reductions, fuel consumption benefits, and emissions reductions. This study includes a benefit-cost analysis to determine the cost-effectiveness of implementing this legislation. The author has not found any previously published papers in the literature assessing the benefits of driver removal legislation. Although the "Steer It and Clear It" law was the primary focus of this analysis, all states with driver removal laws can gain information from the results, and use this information to help apply quick clearance legislation to the traffic problems faced by so many cities and towns today.

Organization of the Thesis

The research presented here is organized into five chapters following Chapter 1, the Introduction. Chapter 2 presents a study of literature on similar research and highlights important findings from that research, and also notes some gaps in research pertaining to quick clearance legislation. Chapter 3 discusses the methodology used in conducting the research for this thesis. The next chapter, Chapter 4, details the results and analyzes the data collected as part of this research. Finally, Chapter 5 summarizes and draws conclusions regarding the findings, and presents some future research opportunities and suggestions.

CHAPTER TWO
LITERATURE REVIEW

Research indicates that incident delay is at a critical point. One study estimates that traffic congestion caused by incidents produces up to 58% of all traffic delay (*6*). The public has also stated their increasing frustration with traffic delays related to incidents, as evidenced by the Federal Highway Administration's 2002 survey regarding public perception of congestion (*7*). In this survey, traffic congestion was the foremost community transportation concern, and drivers reported being dissatisfied with the traffic flow conditions they currently face. The need for reducing traffic congestion is understood by traffic management personnel and transportation decision makers alike. Congestion caused by incidents produces unreliable travel times, which affects businesses in the community as well as employees and travelers caught in traffic.

The costs of incident-related congestion also include environmental issues and safety concerns. Rates of harmful emissions and fuel consumption are known to be negatively impacted by slow-moving and stop-and-go traffic, and incidents blocking the roadway only intensify this problem. Safety issues arise when the roadway is blocked in such a manner that law enforcement and other response personnel must enter the roadway to help clear an incident or provide traffic control services. Large speed differentials caused by fast-moving traffic encountering vehicles slowed or stopped behind an incident can also produce secondary crashes, which have been estimated to make up 1.5% (in Los Angeles) to 35% (in Indiana) of all incidents (*8*).

Incident management is defined in one report as “the process of managing multi-agency, multi-jurisdictional responses to highway traffic disruptions. Efficient and coordinated management of incidents reduces their adverse impacts on public safety, traffic conditions, and the local economy” (*9*). Such programs often consist of methods of incident detection, response mobilization, information dissemination, or clearance strategies, or some combination of several of these approaches. State Departments of Transportation across the country are now investigating different incident management programs to evaluate which provide the best means of improving mobility and travel time reliability. Several studies have contributed to the research effort to summarize states’ experience with incident management programs. One such study, performed by the United States Department of Transportation (USDOT), examined the state-of-the-practice, exploring some of the different methods of incident management currently being utilized in different areas of the country, and measuring the benefits of such programs. The study concluded that, among other issues, defined roles and proper planning are aspects at the heart of a truly successful incident management program (*9*).

One state that has been actively pursuing incident management policies and programs since the 1980’s has been Wisconsin, and it has continued to expand and refine its measures to improve traffic conditions in incident situations. The SmartWays program in place combines different ITS technologies along with legislation and organized agency coordination to work towards the goal of reducing traffic congestion and minimizing incidents’ impacts on traffic. Techniques employed include electronic traffic sensors, closed circuit television cameras, ramp meters, freeway service patrols, variable message signs, and crash investigation sites, as well as an incident clearance law. The listed benefits of the program include improvements to traffic congestion, thereby positively influencing air quality and fuel consumption; faster and more effective agency response in the event of an incident; more efficient freight movement through the area; and up-to-date traveler information to help motorists evaluate travel decisions. (*10*)

Safety improvements, emissions and fuel consumption reductions, and delay savings are all important factors behind the decision to implement an incident management program, and therefore the ability to quantify the specific effects a program has on each factor is vital to comprehending the success of the project. With its focus on improving each of these three significant areas, quick clearance legislation can be an important addition to existing incident management programs.

Effects of Incident Delay

Highway incidents cause significant congestion every day on America's roadways. Incidents that temporarily block travel lanes restrict the roadway's capacity, while demand remains at the previous level, resulting in nonrecurring delay to road users. One study showed that an incident blocking one freeway lane could reduce capacity by 65% for a two-lane, one-way facility (*11*). Frith et al. studied roadway capacity during and following an incident, and found that in the event of an incident blocking at least one lane of a freeway with at least two lanes in each direction, the capacity will be approximately 81% of the expected capacity of the remaining open travel lane(s) (*12*). This estimation reveals that a one-lane-blocked incident on a 2-lane freeway would reduce the facility capacity to 40.5% of the capacity, under the prevailing traffic flow conditions, for the entire duration of the incident (*12*). Another study found a reduction in capacity of 63% for a crash blocking one lane of a three-lane facility (*13*). The significance of this capacity reduction is further emphasized when one considers the peak hour traffic conditions in which incidents frequently occur. Incidents that further reduce capacity can have overwhelming impacts on an already overloaded infrastructure, and cause congestion lasting much longer than the traffic incident itself.

Delay and Travel Time Reliability Effects

Delay, whether caused by major or minor incidents, can cause multiple problems for all affected drivers and vehicles. A study completed for the Florida Department of Transportation summarized some of the key issues involved with traffic delay, which included lost time and productivity, delayed deliveries resulting in increased costs for goods, increased fuel consumption and emissions, increased emergency response times, and reduced quality of life (*14*). Emergency response stakeholders have already looked at the need for signal preemption to decrease response times in many urban areas, due to the issues that arise when emergency vehicles are responding to incidents during times of traffic congestion (15, 16). Many attempts have been made to place a value on the time that congestion delay causes. Nonrecurring delay is generally valued at two to three times the cost of normal, or recurring, traffic delay, due to its unexpected nature (*15*). The Intelligent Transportation Systems (ITS) Deployment Analysis System (IDAS) software developed by the Federal Highway Administration confirms this increased value in their calculations, wherein the standard value of nonrecurring delay is equal to three times that of recurring peak hour congestion delay (*18*).

Travel time reliability has increasingly become a focus for transportation communities because it has such a large impact on road users. Cohen et al. (*19*) states that commuters consider travel time reliability a crucial part of their travel, and reinforces the assertion that unexpected delay is much more costly than expected delay.

Reliability values are even more significant when viewed from the standpoint of the trucking industry, where travel time values are consistently double the normal passenger car costs per hour. The nature of the trucking industry utilizes "just in time" processes that require the delivery of goods at specified times in order to most efficiently operate their production lines (*20*). Therefore, the Transportation Research Board (TRB) has noted the importance of determining the value of travel time reliability, which is critically affected by traffic incidents, and has made it a priority for research. The document published for the Future Strategic Highway Research Program (F-SHRP) is devoted to the summarization of different measures and factors related to predicting travel time. (*22*)

The impacts of incident duration on traffic delay have been studied by many researchers for a variety of applications. Studies have shown that for every one minute of incident duration, traffic is delayed four minutes before returning to normal operation (*20*). The impact of this delay can be tremendous when one considers the wide-reaching effects of vehicles (and their drivers) halted in traffic. A study conducted by Cohen and Southworth indicated that incident delay varies with the square of the incident duration, but that data is insufficient to establish this relationship empirically (*19*). Nevertheless, it is clear that improving incident management by reducing incident duration will consequently improve congestion and travel time reliability.

An FHWA state of the practice report summarized the study results of several examples of incident management programs in terms of their impacts on delay. For instance, the TransGuide program in San Antonio, Texas, which uses a combination of detection and surveillance methods along with information dissemination technologies to help manage traffic incidents, resulted in a delay savings of 700 vehicle-hours per incident (*21*). The 2005 Urban Mobility Report summarized some of the findings regarding freeway incident management programs across the country (*1*). The areas with largest populations benefited most from such programs, but all the study areas experienced at least some benefits, as shown in Table 2.1.

Many incident management programs today involve a freeway service patrol program, and states have found considerable success with this type of practice. Depending on the number of patrol vehicles and the miles of freeway the program

Table 2.1: Freeway Incident Management Reduction Benefits (*1*)

Population Group	Average Covered Freeway Lane-miles		Freeway Hours of Delay (million)
	Lane-miles	Percentage	Delay Reduction
Surveillance Cameras			
Very Large (13)	1,301	45	Delay Reduction Included Below
Large (22)	399	36	
Medium (21)	196	36	
Small (6)	61	27	
62 Area Average	487	40	
62 Area Total	30,183	40	
Service Patrols			
Very Large (13)	2,118	73	136.6
Large (23)	691	63	31.6
Medium (22)	298	56	8.6
Small (6)	161	71	0.2
64 Area Average	796	67	–
64 Area Total	50,947	67	177.0

encompasses, these patrol units can be used in incident detection and verification, in addition to their typical uses for improved incident response and clearance times. Freeway service patrols (FSPs) generally produce a high benefit-cost ratio, indicating the effectiveness of such programs. The FHWA reported that the Minnesota Highway Helper program was shown to produce a delay-savings benefit of $1.4 million per year (*8*). Carson et al. investigated the effectiveness of an FSP in Washington State by considering the reduction in incident duration. This study found that the incident response team (IRT) program put in place shortened incident durations by 20.6 minutes (*24*). Skabardonis et al. studied the success of FSP, and found that the traffic delay in cases where the FSP assisted in clearing an incident was significantly affected by the reduced clearance time that an FSP could provide (*25*). The Hoosier Helper program in Indiana was evaluated using simulation to determine the FSP's effectiveness, and results indicated a yearly delay savings benefit of approximately $3.7 million for a FSP operating 24 hours per day. This simulation study found incident duration reductions of 10 to 15 minutes for FSP responses (*26*).

Travel time reliability can also be an appropriate measure of an incident management program's success, because it is so highly valued. Chen, et al studied travel time reliability and showed that incident information dissemination was a particularly effective way to reduce variability when traffic incidents occur (*26*).

Cohen and Southworth in particular attempted to develop a mathematical model for valuing reliability during an incident, based on specific parameters of the incident and traffic surrounding it, such as incident duration, queue length, capacity of the facility, and number of vehicles per hour among other considerations. This study also utilized the microsimulation software FRESIM to estimate the average flow of vehicles from the queue built up during the incident. The results of their study demonstrated the need for additional research in the area of reliability values, although they were able to determine that if an incident management program is unable to reduce travel times but manages to reduce travel time variability, the program can still be cost-effective (*19*).

Safety Effects

Safety is another major concern with nonrecurring incident delay. First, the safety of other drivers in the network is at risk, because secondary incidents resulting from large speed differentials make up a significant share of all traffic incidents, and are often more serious than the primary incident (*23*). In fact, one study showed that for each additional minute of incident duration, the secondary incident occurrence probability rose 2.8% (*23*). Maximizing the efficiency in clearing an incident is therefore paramount to ensuring safety of the traveling public.

An evaluation of the FIRST Program in Minnesota notes the difficulty in obtaining the actual numbers of secondary crashes, since this is not typically an item utilized in incident reports (*8*). States and even local jurisdictions within states vary greatly on what constitutes a secondary crash. Two methods have generally been used to determine the percentage of secondary crashes among total incidents, and both are considered faulty at some level. The first, which bases the categorization of a crash as “secondary” if it occurs within a specified proximity of distance and time of another traffic incident, can either over- or under-estimate the actual values, since they are merely based on an algorithm. The second method of classifying relies on human operators' surveillance of incident videos, which is ultimately subjective due to varying opinions of operators across the nation, as well as factors such as camera placement (*8*). The difficulty in estimating secondary crash rates is outlined by the varied results of studies devoted to the issue, but all can agree that the longer an incident remains un-cleared, the more the traffic will be affected.

The amount of time incident responders must be exposed to the hazards of traffic is another key issue when incidents occur, and the risk is greater on higher-speed facilities such as freeways. In 2001 alone, 34 incident responders were killed when struck by another vehicle while outside their own emergency vehicle (*28*). The actual effect of increased incident duration on the safety of incident response personnel is not exactly a quantifiable risk, although it is an issue at the forefront of motivations for incident management practices.

Nearly all studies considered in this review noted some safety benefits, perceived and/or quantified, provided by implementing an incident management program. Before and after crash statistics gathered for the San Antonio TransGuide System showed a 35% reduction in primary crashes as well as a 40% reduction in secondary crashes, and an overall crash reduction of 41%, due to the information dissemination methods used in this management program (*21*). The I-95 Traffic and Incident Management Program in Philadelphia was credited with reducing freeway traffic incidents by 40%, and reducing the severity rate of those incidents by 8% (*9*). In Wisconsin, transportation officials enacted a freeway tow truck service on I-94 called the "Gateway Patrol," which was able to reduce secondary incidents by 14% after implementation. This study assumed that a secondary incident was a crash occurring within one hour and within two miles upstream of a primary incident (*29*). Another study focused on the effect of changeable message signs (CMS) employed on a freeway in Toronto using the video method previously described, and found that using CMS reduced the secondary crash rate from 16.8% to 5.2% of the total number of crashes for the period of study (*30*).

Secondary crash reductions were also studied in two Hoosier Helper evaluation reports. The first of these reports involved an investigation into secondary crash savings as it relates to reduced incident duration. This study found that every 10-minute reduction in incident duration results in an 18.5% reduction of secondary crashes in winter, and a 36.3% reduction in all other seasons (*23*). Using the results of this first study, the second report went on to value the secondary crash reductions produced by the 24-hour Hoosier Helper FSP, and determined a yearly benefit of $1.5 million due to secondary crashes alone (*26*).

Energy and Environmental Effects

Emissions are known to increase with variable speeds, caused by accelerations and decelerations, as opposed to constant speeds. These speed changes can be the result of incidents reducing the capacity of the roadway and causing traffic delays.

In order to combat the effects of congestion on the environment, incident management programs are often implemented as part of a Congestion Mitigation and Air Quality (CMAQ) improvement plan for a region or metropolitan area. For example, San Francisco initiated a freeway service patrol program in 1992, and five years after its inception, the patrol units had already assisted 90,000 drivers (*31*). By reducing incident durations through faster response times, the program has helped reduce incident congestion and the environmental effects of that congestion. One study estimated substantial emissions reductions of 32 kilograms per day of hydrocarbons, 322 kg/day of carbon monoxide, and 798 kg/day of nitrous oxides for the San Francisco freeway service patrol, which are emissions likely to be increased through stop-and-go driving and frequent idling (*31*). Another study estimated a hydrocarbon emissions reduction of 91 kg/day due to the implementation of Houston's citywide traffic management center, called TranStar (*31*).

Wasted fuel is another serious impact of delayed traffic. The 2005 Urban Mobility Report examined this issue, and determined that of the small urban areas chosen for the study, an average of 8 gallons per year per traveler was wasted because of congested conditions. In contrast, travelers in the largest cities wasted an average of 36 gallons per year of fuel. Of the 85 urban areas studied, the twelve largest cities accounted for two-thirds of all delay, which leads to the conclusion that increased congestion delays bring about increased fuel consumption. Furthermore, 2.3 billion gallons of fuel were wasted in the year of study in all 85 of the urban areas combined. This immense waste of resources leads to billions of dollars lost, a cost endured by both the average commuting travelers as well as businesses in the community. (*1*)

Reduced fuel consumption is therefore an issue of importance for metropolitan areas considering implementing incident management programs. The San Antonio TransGuide System reports an average benefit of 2600 gallons of gasoline saved per incident due to the program, based on before and after data (*9*). The Massachusetts Motorist Assistance Program (MAP) was reported in 1997 to generate an area-wide fuel savings of $2.5 million, based on an average fuel cost of $1.50 per gallon (*32*).

Experience with Quick Clearance Legislation

The possible benefits of quick clearance legislation impact a wide range of problems faced in today's transportation network. Previous research efforts have mainly focused on the state of the practice across the nation, while this research will be involved in a direct analysis of benefits to the stakeholders involved. These benefits can include monetary issues, such as saved fuel and increased productivity, and quality of life issues, such as enhanced safety of responders and motorists as well as air quality improvements. In order to get an idea of the effects of shortened incident duration, the NCHRP has conducted some simulation runs to estimate non-recurrent congestion changes with specified traffic and crash parameters, but has not studied fully the impacts of legislation aimed at decreasing this congestion (*3*).

Incidents blocking a lane or more of traffic can reduce the roadway capacity significantly. This substantial decrease in the ability of the system to accommodate the ever-increasing number of vehicles on the roadway is the core of the incident congestion problem. In addition, increased incident duration drastically increases the time it will take for traffic to return to normal conditions. With the roadway affected in such a manner, law enforcement and response personnel cannot arrive on the scene as quickly as desired, delaying traffic even longer. If such an incident were moved to the shoulder as soon as it had occurred (in cases where the driver can still operate the vehicle), the vehicle removal process would be completed before law enforcement arrived, and traffic can return to normal flow much faster. Such is the basis for South Carolina's "Steer It and Clear It" law, which focuses on those minor crashes and stalled vehicles that drivers can move out of the travel lanes (*33*).

South Carolina's law states, "If a disabled vehicle or a vehicle involved in an accident resulting only in damage to a vehicle is obstructing traffic, the driver of the vehicle shall make every reasonable effort to move any vehicle that is capable of being driven safely off the roadway… so as not to block the flow of traffic" (*34).* The law also recommends the posting of signage to inform the public about the law's existence, and to instruct them on how to follow it. In addition, it does not hold the driver who moved their vehicle at fault in the incident solely based on their following this law.

Many states have recently passed quick clearance legislation, and most seem pleased with its effects. Connecticut has the oldest law, which was passed in 1994 (*3*). The 22 states shaded in Figure 2.1 have already implemented driver removal legislation.

Several states are now considering this type of legislation, and are interested in finding information about the experiences of the states that already utilize this law. Therefore, the results of this research can have far-reaching effects on other states that have already implemented or are considering implementing such legislation, or who are contemplating policies that are more elaborate. Such enhanced policies might include the addition of quick clearance towing laws for heavy vehicles and cargo removal, or authority hold-harmless provisions that protect the tow company and responding agency from litigation by the owner of the towed vehicle or cargo. (*3*)

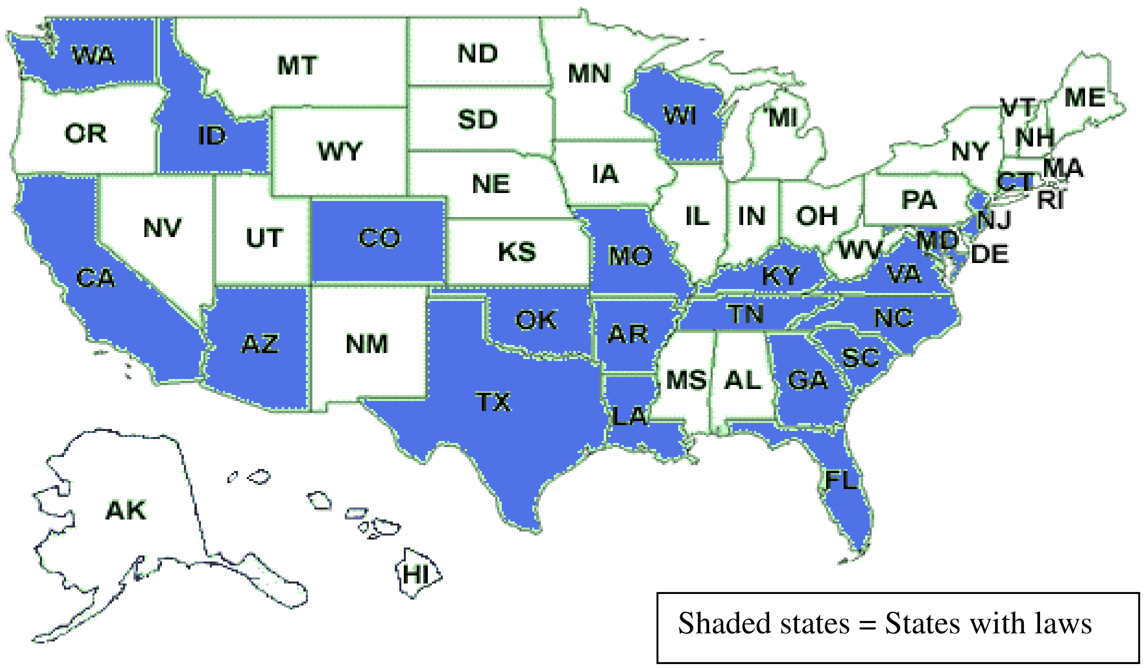


Figure 2.1: States with Driver Removal Laws

Delay and Travel Time Reliability Effects

NCHRP Synthesis 318 summarizes the components of incident clearance legislation, and provides some preliminary study findings for the effects that quick clearance might have on delay. Surveyed agencies performed minor incident (lasting less than 30 minutes) clearance activities in an average of 26 minutes. In addition, a model was developed and simulated using FRESIM to estimate the effects that different durations could have on congestion levels. The results of this simulation can be seen in the graph in Figure 2.2, and it shows intensified traffic congestion levels with increased incident durations. A substantial growth in congestion levels is especially evident for

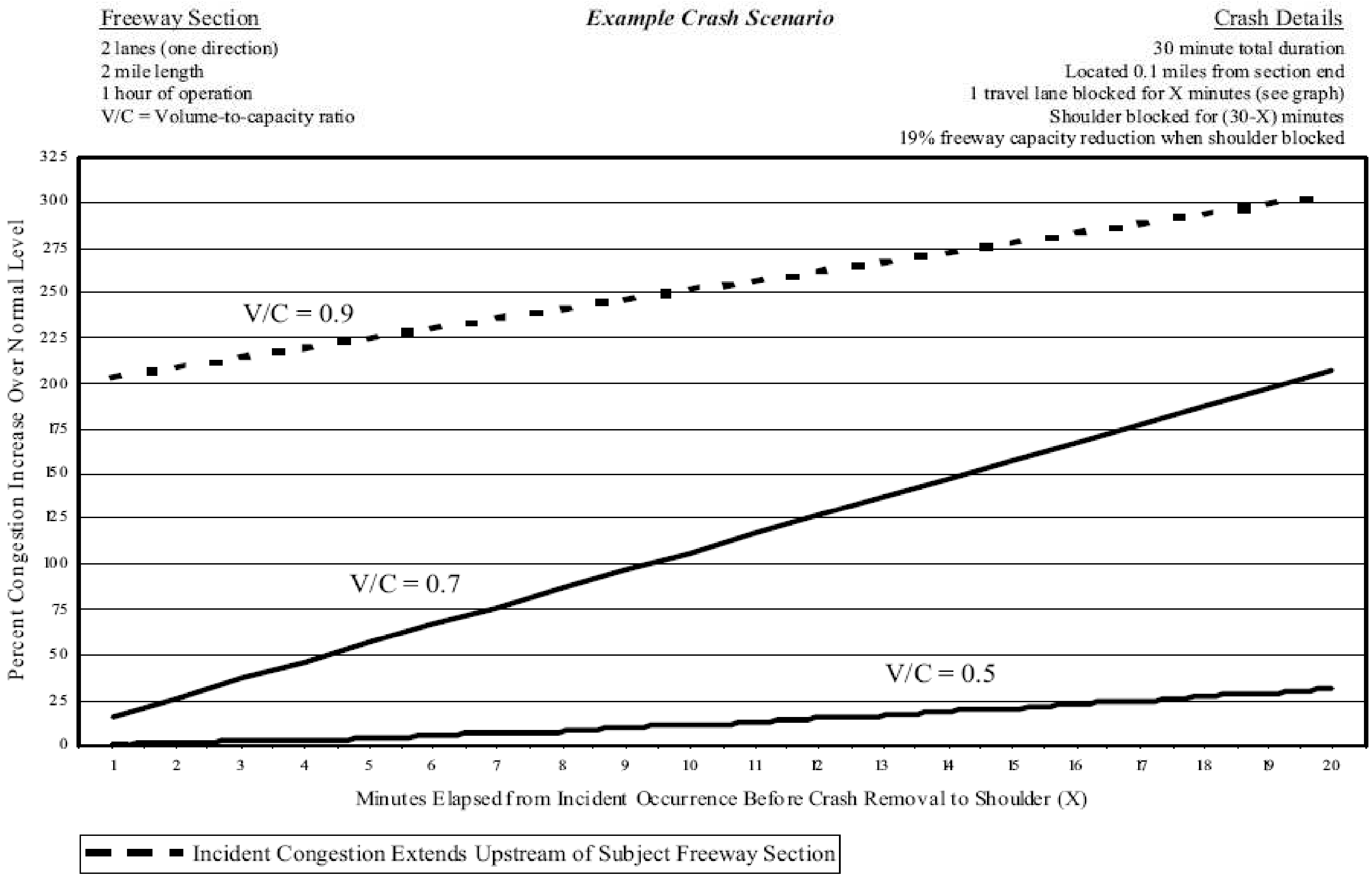


Figure 2.2: Simulated Effect of Duration on Traffic Congestion (*3*)

increased durations when the volume-to-capacity ratio exceeds 0.7. This study utilized historical data for response and clearance times to determine the range of durations modeled. The model was run only for relatively short incidents, because the authors of the study presumed that a minor incident would not occupy the travel lane any longer than 20 minutes. (*3*)

Safety Effects

The Highway Patrol in North Carolina recently stated that their Quick Removal law has resulted in a drastic decline in secondary incidents, due to reduced traffic delays in the travel lanes (*35*). Wisconsin also implemented a program involving crash investigation sites, which attempts to enhance safety by directing people involved in crashes to a safer location than the shoulder of a high-speed freeway facility in order to exchange insurance information and wait for response personnel to arrive. This program reduced secondary crashes due to the quicker clearance of vehicles (*29*).

Energy and Environmental Effects

Fuel consumption and emissions reductions were part of several studies of incident management programs previously discussed. Because quick clearance legislation is relatively new to the transportation world, studies that model or estimate these benefits are difficult to find. Complete knowledge of the actual benefits will only be available after policies have been in place long enough to gather sufficient data for a before and after case study. However, by utilizing similar air quality monitoring practices from previous studies, estimations of these types of improvements can be obtained to a relative degree of satisfaction.

CHAPTER THREE
METHODOLOGY

Incident duration refers to the total time an incident affects traffic flow, from the time the incident occurs to the point at which traffic returns to normal flow conditions. It can normally be determined by the sum of the detection and verification, response, clearance, and recovery times. Many incident management programs are being studied and implemented across the country to try to reduce one or more of these phases. Driver removal legislation such as the "Steer It and Clear It" law is primarily aimed at minimizing the first three phases, in that the driver takes responsibility for clearing the vehicle in minor incidents. Completing the clearance step of the process before emergency response teams arrive on the scene means that traffic can begin to recover to normal conditions almost immediately, and the incident duration would no longer be dependent on the detection and response phases, but solely on the clearance phase. The following sections present the methodology adopted in estimating the effects of the "Steer It Clear It" law on a highway network in South Carolina.

Microscopic Simulation

The evaluation portion of this research was conducted in PARAMICS, which is a behavior-based, microscopic simulation package for modeling highway or freeway networks. PARAMICS allows many different innovative research applications through a flexible Application Programming Interface (API). The API allows users to customize many features of the underlying model and develop their own modules to interface with PARAMICS. The software can also model various real-time traffic management strategies. This research project was a part of a South Carolina Department of Transportation sponsored study, where different models of freeway segments in the state were created in PARAMICS in order to model and evaluate incident management strategies. This simulation tool was used in the research to help model scenarios in realistic situations that would not be possible to test in the real world. It portrays the effects of an incident on the traffic flow and vehicles in the network, and provides statistics such as average speed, network delay, and delay per vehicle.

Calibration and Validation of the Model

Simulations were run on a network in PARAMICS depicting a stretch of I-85 in Greenville, South Carolina, from mile marker 40 to 51. The location of the incident was fixed at the Exit 48 interchange for Laurens Road, as this location has one of the highest incident rates in the area. A relatively urbanized area, this portion of interstate sees an average daily traffic (ADT) count of approximately 47,000 vehicles per day. Figure 3.2 shows the model of the freeway network used in this research. To ensure that the simulation network correctly represented real-world conditions, the author first collected information about the site and gathered data such as travel times, traffic volumes, signal timings, queues at signals and ramps, and signing and marking plans. The model itself was built using GIS maps and converting these to PARAMICS files using the Shape to PARAMICS tool. Subsequent to finalizing the model's geometric and operations characteristics, traffic volumes were added and preliminary simulation runs were performed. During the initial simulation run, travel times were gathered for vehicles traveling through the network. These travel times were then compared to the known travel times collected on site. In order to match the simulated travel times with the actual times, the author performed a process of calibration. These calibrations involved adjusting PARAMICS default values that govern traffic and individual vehicle behavior and that account for the stochastic nature of the modeling software. After adjusting these values, the model was simulated again without an incident present. This process was repeated until the travel times found in simulation corresponded to those in the field, and the model was considered validated.

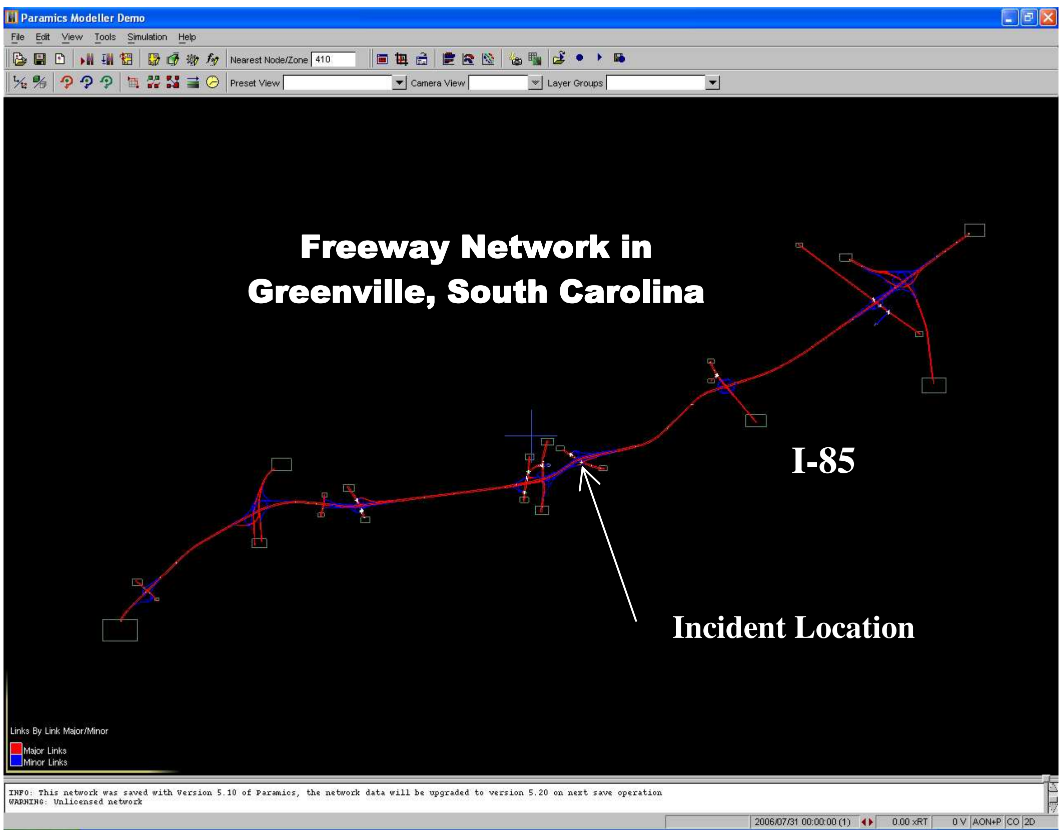


Figure 3.1: Freeway Network Simulation Model

Incident Simulation

Inputs for the PARAMICS simulation can include characteristics of incidents such as incident duration, location, and severity, or the number of lanes blocked. These "inputs" can either be defined by the user or occur randomly. Randomness within the program is an important feature because modeling driver behavior is difficult at best, due to the highly subjective nature of the decisions individuals make. To evaluate the driver removal law, incident duration was randomly generated by the simulation model. With this research, the input for incident location was considered constant so that comparisons of the "before law" and "after law" conditions would be consistent. Incident severity (number of lanes blocked) was set at one lane, since driver removal laws mainly apply to minor incidents.

Data Collection and Procedure

"Before Law" Condition

For the "before law" condition, the researchers wanted to accurately capture the effects of the driver removal law, and therefore needed to verify the average time it took for incident responders to assist with an incident. A study in Wisconsin showed that first responding law enforcement officers arrived at the scene of an incident an average of 9.8 minutes after the incident occurred (*36*), while freeway service patrols usually average a response time of 9 minutes (*9*). In addition, historical incident data from law enforcement agencies in South Carolina was used to determine the mean incident clearance time of minor incidents at the study site. Incidents classified by the researcher as minor incidents were assumed to be those crashes that had no injuries or fatalities, and to be blocking one lane of traffic. Using this historical data and the average response times described above, the simulated incident duration was found by selecting the duration from a range of 10.5 to 19.5 minutes with a 95% confidence interval, assuming a normal distribution. This allows 9 to 10 minutes for incident responders to arrive, per the national average, and between 2 and 10 minutes to clear the minor crash. The range in clearance times was based on expert opinion from incident management personnel, also at the Greenville TMC. This information was used as the base situation, or the "before law" condition, and was input into the PARAMICS program. A collection of incidents was generated using this mean and distribution and simulated in PARAMICS for the "before law" condition.

"After Law" Condition

For the "after law" condition, the range from which the PARAMICS program assigned random incident clearance times was much lower. It was necessary to determine the average length of time a driver took to clear his/her vehicle from the roadway after an incident occurred, provided the incident was minor enough that the vehicle could be moved without a tow truck. The low end of the range was estimated based on the suggested value of 2 minutes as presented in the NCHRP Synthesis 318 report (*3*). Based on the average authority response times of approximately 9.5 minutes mentioned previously, the upper limit of the range was conservatively set at 10.5 minutes in order to capture the incidents affected by driver removal, rather than authority removal. This range of 2 to 10.5 minutes was assumed to have a normal distribution, with a mean duration of 6 minutes and a standard deviation of 2 minutes, based on a 95% confidence interval. These cases were then simulated with random incident clearance times automatically generated for each case, within the specified range. Figure 3.2

demonstrates the procedure for simulating these two conditions for the incident clearance legislation.

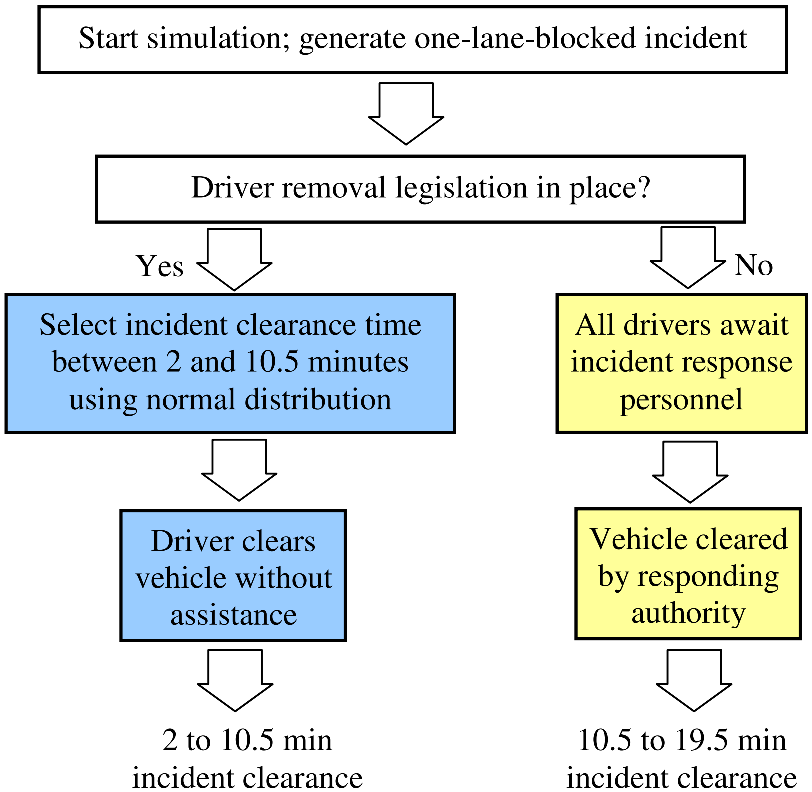


Figure 3.2: Incident Clearance Simulation Process (100% Compliant Drivers)

Initially, analysis was completed for the "after law" scenario assuming that all drivers would be aware of and follow this law after its implementation. To demonstrate a more realistic situation, the analysis assumed four different scenarios consisting of 100%, 75%, 50% and 25% of people following the law in the "after" condition. Unless otherwise specified, all calculations for "after" conditions assume 100% compliance.

Sampling Strategy

For each simulation run, values for vehicle-hours of travel (VHT) were collected. Using fifteen of the “before law” and “after law” cases in the initial step of analysis, an average VHT was calculated for each scenario. Using these values, the mean and variance of the VHT outputs of the initial cases were determined, and the researchers used the statistical formula in Equation 3.1 to determine the required sample size. The sample size formula was used to determine both the number of required runs for both “before law” and “after law” scenarios. The initial standard deviation found for the fifteen simulation runs was 37.7 vehicle-hours, and the standard error was 8.5. Using this formula, the sample size was determined to be 76 cases. Consequently, the researchers used a sample size of 76 for both the “before law” and “after law” sets of cases, to achieve an acceptable level of significance.

$$n = \frac{1.96^2 \times s^2}{E^2} \qquad \text{(Equation 3.1)}$$

Where: n = number of samples required

s = initial standard deviation

E = standard margin of error

Benefit-Cost Analysis

Delay Analysis Strategy

After determining the ranges for incident clearance times for both the “before law” and “after law” conditions, the simulations were run in PARAMICS. First, 76 “before law” cases were run, and the vehicle-hours of travel (VHT) were determined from the output and measured in vehicle-hours, which was calculated based on all vehicles throughout the network. Next, the same procedure was performed for all 76 of the "after law" cases. For each simulation run, the total VHT was recorded along with the number of vehicles in the network. A mean delay for each condition was then calculated by subtracting the "after law" average VHT from the average VHT for "before" in order to draw comparisons between the two conditions. To evaluate the significance of the difference in delay, the researchers completed statistical analyses on both sets of VHT data, testing the difference between the mean VHTs of the "before law" and "after law" conditions.

Subsequently, the authors researched available data on the monetary value of time spent in congestion. Using these values, the costs associated with each condition's delay were determined. Subtracting the "after law" cost of delay from the "before law" value produced a dollar value of delay savings per incident.

Environmental Impact Analysis Strategy

This research included the study of carbon monoxide (CO), particulate matter (PM), nitrous oxides (NOX), hydrocarbons (HC), and volatile organic compounds (VOC) as the emissions affected by incident clearance legislation. The EPA program Mobile6 was used to estimate the average emissions rates of three different vehicle types: light-duty gas vehicle (LDGV), heavy-duty gas vehicle (HDGV), and heavy-duty diesel vehicle (HDDV), for a wide range of speeds. The PARAMICS Monitor software package interpolates emissions for vehicle speeds, measured in miles per hour (mph) falling between the input values found in Mobile6. Using this procedure, emissions values are determined in PARAMICS and given as a total output for the entire simulation run. Averaging the values for the "before" and "after" cases gives an average pollution rate for each type of incident. IDAS documentation gives average costs for each of these pollutants, and so the emissions values found through simulation were converted to dollar amounts.

Fuel consumption rates for each vehicle type were also researched. Gathering national statistics and South Carolina-specific data allowed the author to determine a weighted average fuel consumption for the two different heavy duty vehicle types used, including both heavy-duty gas and diesel vehicles. The weighted-average fuel consumption rates were then converted to a rate of gallons per second at each speed (5 mph increment) for input into PARAMICS Monitor. PARAMICS totaled the fuel consumption in each vehicle type category based on the length of the simulation run, and these data were used to find the difference between the two simulated scenarios. Average fuel costs for South Carolina were then used to convert the fuel consumption in gallons into dollar values for the benefit-cost analysis.

Cost Calculations

Determining the costs for South Carolina's Steer-It Clear-It law involved advertising costs and signage. South Carolina's current practice involves posting signs along the freeway throughout the state. This research assumed that one sign was posted on each side of the interstate, spaced at 5 miles for all interstate miles in Greenville County. Additionally, one freeway billboard sign was considered as part of the costs. Advertising costs included a radio station advertisement and a television ad to be aired on local stations. All costs involved were then summed to determine the total cost of implementing the Steer-It Clear-It law at the Greenville site.

CHAPTER FOUR
ANALYSIS

Evaluating the effects and quantifying the possible benefits of the "Steer It Clear It" law required comprehensive examination of specific measures of effectiveness. The delay savings MOE was chosen for this study because it represents the greatest effect that minor incidents such as those affected by quick clearance legislation can have on the roadway network and surroundings. PARAMICS provides a variety of output results including incident clearance time, vehicle-hours traveled (VHT), and emissions and fuel consumption rates. This study focused on the environmental and fuel consumption effects in addition to delay savings.

Calibration and Validation

Calibration of the simulation model was achieved by adjusting the default parameters that PARAMICS uses to model driver and traffic behavior. The mean driver reaction time and mean headway (in seconds) were the two adjusted values. The reaction time was set at 1.0 seconds to fit average driver behavior for this portion of I-85. Headway was set at 1.0 seconds to correspond to driver aggressiveness for this type of weekday peak-hour traffic. The model was validated by matching the simulated travel times, for vehicles traveling from one end of the freeway network to the other, to those found in the field.

Legislation's Effects on Delay

When the author completed the simulation runs, the mean incident duration for the "before law" condition was found to be 15.5 minutes, and was 5.9 minutes for the "after law" condition (assuming 100% compliance). These duration values indicate that PARAMICS correctly simulated the incidents as designed.

After completing the simulation runs for both sets of cases, the vehicle-hours traveled (VHT) on each link for each case was tallied, and the average VHT for each condition was calculated. The mean total VHT of the "before law" condition was 9,819.7 vehicle-hours, while the "after law" condition produces a VHT value of 9,766.4 vehicle-hours. Subtracting the VHT for the simulations run with the law in place from the "before" condition VHT gives a difference that can be described as delay savings. A full

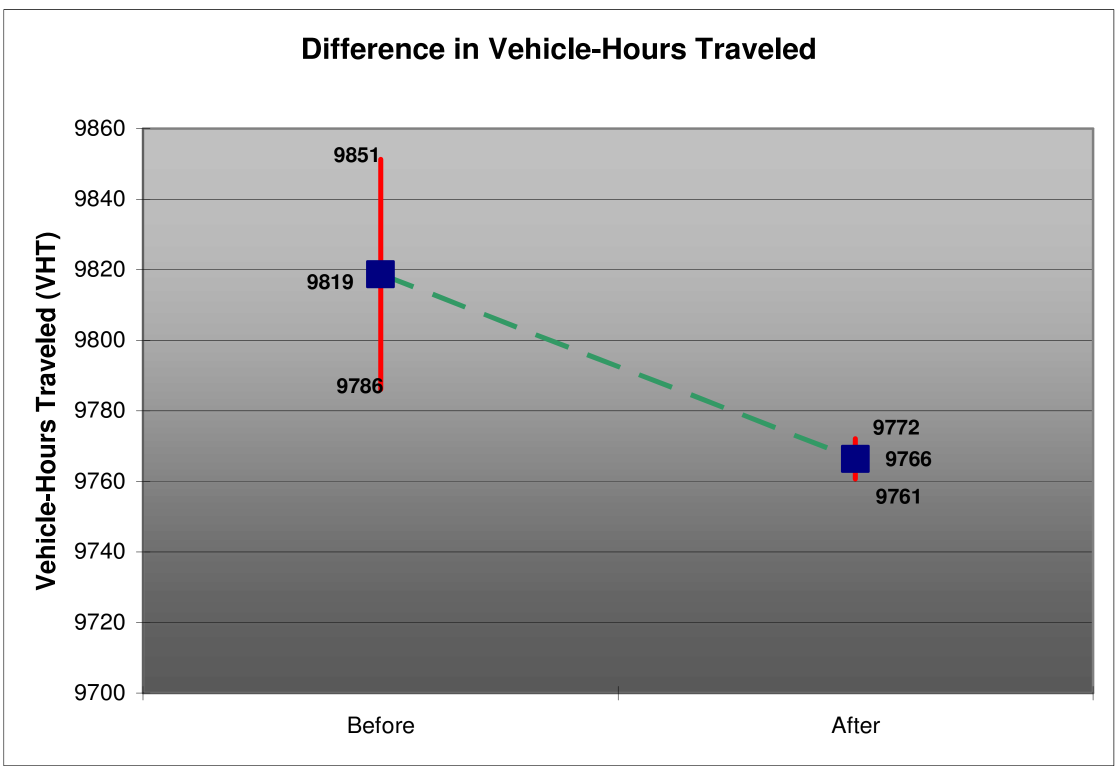


Figure 4.1: "Before" and "After" Comparison of VHT

summary of the “before” and “after” case data can be found in Appendix A at the end of this report.

The results show that incident clearance legislation can reduce delay by approximately 52 vehicle-hours for a minor incident with one travel lane blocked in the network. In other words, relying on traditional incident clearance measures contributed an average of 52 more vehicle-hours of delay per minor incident compared to cases where drivers fully complied with the “Steer It and Clear It” law. The effect of the reduced incident clearance time on the incident delay, represented as VHT, is shown by Figure 4.1. Each set of three numbers again refer to the mean, upper and lower limits of the expected network delay, using a 95% confidence interval. The effect of the differing percentages of compliant drivers can be seen by the graph in Figure 4.2.

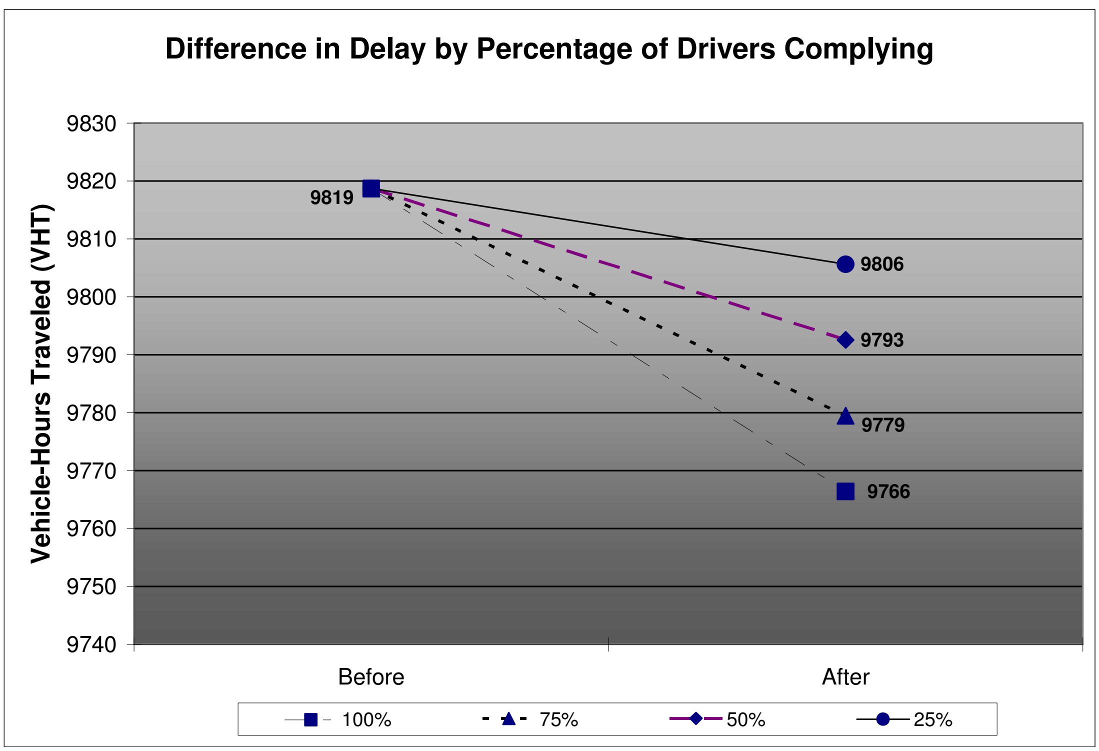


Figure 4.2: "Before" and "After" Comparison Based on Percentage of Drivers Complying

This sensitivity analysis considers the effects of differing percentages of drivers complying with the law as it is written. Completion of this analysis allowed for analyzing realistic situations in which not all drivers will be aware of the law, or in which drivers aware of the law are not able to follow it. In addition, some drivers may be aware of the law but instead choose not to follow it based on their lack of familiarity with the consequences of moving their vehicle before law enforcement arrives, since this practice has been standard in most jurisdictions for so many years. Total delay values and savings for the differing percentages of compliant drivers for the "after law" condition are shown in Table 4.1. The values can be interpreted to indicate that if 75% of drivers involved in a minor incident to which quick clearance legislation would apply in fact comply with the law and move their vehicle as directed, the delay savings would be 39 vehicle-hours on average. For a scenario in which only 25% of drivers comply, the delay savings would be 13 vehicle-hours for the simulation network.

Table 4.1: Delay Savings for Percent of Drivers Complying with Law

	"After Law" Condition Results			
Percent of Drivers Compliant (%)	100%	75%	50%	25%
VHT (vehicle-hours)	9766.4	9779.5	9792.6	9805.6
Delay Savings (vehicle-hours)	**52**	**39**	**26**	**13**

Discussion of Results

Upon consideration of the delay savings of 52 vehicle-hours per incident with drivers complying with the Steer It and Clear It law 100% of the time, this value may seem unexpectedly high in proportion to the short duration of incident. However, consider that PARAMICS calculates VHT for the entire network of vehicles throughout the entire simulation run. Due to the nature of the volume-capacity relationship, the freeway's capacity is greatly reduced by the "before law" incident because it remains in the travel lane approximately for an additional 10 minutes. Assuming that traffic patterns for the Greenville site are consistent with those in the studies which state that traffic takes four times as long as the incident to return to normal operating conditions, this length of time would allow for a large number of vehicles to be affected. Therefore, vehicles that are not even on the freeway at the time of the incident can be impacted by congestion on the freeway spreading to ramps and the arterials upstream of the incident. Furthermore, the reduced capacity carries a significant impact to those vehicles in the vicinity of the incident. The incident effects experienced by every vehicle in the network contribute to the difference in delay, which may explain the higher-than-anticipated 52 vehicle-hours of savings.

In addition, a savings of 52 vehicle-hours signifies the potential delay savings due to 100% driver compliance with the law. For 75% compliance, 39 vehicle-hours of delay can be saved. If 25% to 50% of drivers comply, the savings can be 13 to 26 vehicle-hours. These values probably reveal a more realistic view of the delay savings possible with implementation of quick clearance legislation, since it is unlikely that 100% of drivers will be aware of the law, and of those that are aware, some will be unable or unwilling to comply. The exact percentage of drivers who may fit into any of these three categories (unaware, unable or unwilling) is not currently known due to the early stages of such legislation as well as the lack of research available on the effects of such programs.

On the other hand, one might question the significance of the 52 vehicle-hours, considering that the entire network consists of 47,000 vehicles during the simulation run time. Utilizing a 95% confidence interval, the highest VHT values for the "after" condition are not exceptionally less than the lowest values for the "before" runs. To test the significance of the data, the author performed a statistical one-tailed t-test for comparing the "before" and "after" means. The method used to determine the *t* statistic is given by Equation 4.1.

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2} * (\frac{1}{n_1} + \frac{1}{n_2})}} \qquad \text{(Equation 4.1)}$$

Where: $\overline{X}_i$ = Mean of group *i*
n_i = Number of samples in group *i*
s_i = standard deviation of group *i*

Using this formula, the *t* statistic was determined to be 1.657, which gave a resulting p-value of 0.046, signifying that the two means were indeed different for the chosen 95% level of confidence. The slightly higher p-value (somewhat close to 0.05, the value for α in this case), however, indicates that the reduction, while statistically significant, may have less real-world significance than anticipated. After all, 52 hours distributed among 47,000 vehicles equates to an average delay per vehicle of about four seconds. However, in view of the large number of minor incidents that occur on freeways each year, the savings can add up to significant time savings. Additionally, considering that some vehicles are much more heavily impacted than others, and many pass through the network on arterials completely unaffected by the incident, distributing the delay evenly to all vehicles in the network is an incorrect assumption. Those vehicles nearest the incident experience much heavier traffic congestion and therefore must more incident-related delay than vehicles in the rest of the simulation network.

Environmental Effects of Legislation

As many incident management studies suggest, the impacts of a quick clearance law can be evaluated by several performance measures, including fuel consumption and emissions. This research considered the change in both of these MOEs before and after implementation of the law by simulating the two different conditions and gathering data for each simulation run. Mobile6 emission and fuel consumption rates were input in PARAMICS Monitor, allowing the simulation software to compute the actual emissions produced and fuel consumption experienced by the entire network. These inputs were based on vehicle characteristics at specific speeds, such that a certain emissions or fuel consumption rate was identified with a particular speed. PARAMICS then had to interpolate rates that did not fall directly onto a given data point. The Monitor program calculates the cumulative emissions and fuel consumption on each link in the network at specified intervals, which are usually about 5 seconds. This allows the user to consider only the last number of the simulation output in order to identify the actual total pollutant emission or fuel consumption amount.

Having calibrated the network for 16.5% heavy trucks, it is apparent that several different types of vehicles are represented at this site. Each vehicle class has different emitting properties, as well as different fuel consumption rates. These differences are taken into account by the Mobile6 software in the process of producing rates for input. In addition, PARAMICS Monitor allows for separating vehicles by the type of fuel used, since this characteristic also affects emissions.

Emissions

After completing the simulation runs, PARAMICS provides outputs of each of the measured emissions rates. Analysis of this data reveals a general trend downwards for all but one of the five measured emissions. The data is summarized in Table 4.2. All emission rates and differences are given in grams, the PARAMICS output unit. As evidenced by the table, THC, VOC, CO and NOX emissions were reduced after implementation of the quick clearance legislation. This decrease is expected, due to the reduced traffic congestion allowing vehicles to remain at speeds that are more constant. PM emissions actually showed an increase after the law was in place. This increase is probably due to the fluctuations in rates when vehicles are idling, and the emission properties of PM are heavily reliant on this traffic characteristic (37). These idling vehicle emissions were not modeled in PARAMICS due to the nature of the speed-emission rate graph input into Monitor, in which the emission rate declined as speeds decreased instead of giving higher emission values at speeds of 0 mph.

Table 4.2: Emissions Rates for "Before" and "After" Conditions

	Emissions Rates (in grams)			
Pollutant	Before Law	After Law	**Difference**	**% Change**
Total Hydrocarbons	41,803	40,828	**976**	**-2.33%**
Volatile Organic Compounds	38,114	37,202	**913**	**-2.39%**
Carbon Monoxide	371,850	366,259	**5,591**	**-1.50%**
Nitrous Oxides	173,310	172,573	**737**	**-0.43%**
Particulate Matter	35,365	35,434	**-70**	**+0.20%**

When taking into account the sensitivity analysis conducted on the percentages of people following the law, the data shows smaller benefits for decreasing populations complying. A summary of the percentage points of change seen by each of the five pollutants for each percentage category is shown in Table 4.3. Appendix B also gives graphical representations of these changes.

Table 4.3: Percentage Change in Emissions Due to Law

	Percent Change Between "Before" and "After" (%)			
Pollutant	100%	75%	50%	25%
Total Hydrocarbons	2.33%	1.75%	1.17%	0.58%
Volatile Organic Compounds	2.39%	0.56%	0.37%	0.19%
Carbon Monoxide	1.50%	1.13%	0.75%	0.38%
Nitrous Oxides	0.43%	0.32%	0.21%	0.11%
Particulate Matter	-0.20%	-0.15%	-0.10%	-0.05%

Fuel Consumption

PARAMICS also modeled fuel consumption of different vehicle types and different vehicle classes. The output is the total fuel consumption, measured in gallons, for the entire network, all vehicle types combined, for gas and for diesel fuel. This output is summarized in Table 4.4.

Table 4.4: Simulated Fuel Consumption for "Before" and "After" Conditions

	Fuel Consumption (in gallons)			
Type of Fuel	Before Law	After Law	**Difference**	**% Change**
Gas	5,424.8	5,409.1	**15.7**	**-0.29%**
Diesel	2,623.0	2,627.5	**-4.5**	**+0.17%**

Regular gasoline consumption was decreased after the law, although the change was minor at only -0.29%. Diesel fuel consumption increased by 0.17% for the "after" set of simulations, which conflicts with the anticipated results. However, the software programs did not model the idling traffic's fuel consumption due to a limitation of the input rates, so these values are based simply on the average speeds on each link. The percentage changes for each of the four categories of the "after" scenario are shown in Table 4.5. Graphs depicting the changes in fuel consumption are also included in Appendix B.

Table 4.5: Percentage Change in Fuel Consumption Due to Law

	Percent Change Between "Before" and "After" (%)			
Type of Fuel	100%	75%	50%	25%
Unleaded Fuel	0.29%	0.22%	0.14%	0.07%
Diesel Fuel	-0.17%	-0.13%	-0.09%	-0.04%

Benefit-Cost Analysis

Using the benefits found in the results discussed previously in this chapter, a benefit-cost analysis was conducted. The following pages describe the calculations performed in this analysis and the values that were obtained.

Benefit Calculation of Delay Savings

Within the ITS Deployment Analysis System software, calculations for travel time values were completed to perform benefit cost analyses. This software provided the value of time of $16.96 per vehicle per hour for commercial vehicles, in 1995 dollars (*18*). After adjusting for inflation, assuming a 3% inflation rate, the value becomes

$24.18 in 2007 dollars. The IDAS software also provided a value of time for passenger cars of $9.63 in 1995 dollars, which adjusts to $13.73 in 2007 dollars. This research took a conservative approach to the issue of travel time reliability and assumed that delay due to this type of minor crash would be valued at the base value of time given by the IDAS software. The network used in this study had already been calibrated for an average of approximately 16.5% trucks, which means that passenger cars made up the remaining 83.5% of vehicles. The resulting weighted time value was determined as follows:

($13.73 × 0.835) + ($24.18 × 0.165) = $15.45 per vehicle per hour of delay

Using these values, the benefit of reduced delay can be determined by multiplying the dollar value of delay time by the number of vehicle-hours of delay experienced in the network:

$15.45 per vehicle per hour × 52 vehicle-hours of delay = $803 per incident

Utilizing driver removal legislation will therefore have the potential to reduce the costs incurred to road users and the community by an average of $959 every time a minor incident occurs in this location of South Carolina, if all driver(s) of the involved vehicle(s) promptly move vehicles from the traveled roadway prior to the arrival of the first responders. If varying percentages of drivers follow this law, the delay savings will translate to average savings to the community of the figures shown in Table 4.6.

Table 4.6: Delay Reduction Benefit per Incident Due to Law

	Delay Savings Benefit by Percent Compliance			
Percent of Drivers Compliant (%)	100%	75%	50%	25%
Delay Savings (vehicle-hours)	52	39	26	13
Dollar Benefit of Reduced Delay ($)	**$803**	**$603**	**$402**	**$201**

Benefit Calculations of Environmental Effects

PARAMICS outputs give the units of pollutants measured in grams, while costs for pollution are typically given in terms of dollars per ton of emissions; therefore, the outputs were converted into tons. Using IDAS Documentation, values for each of the specified pollutants were converted into 2007 dollars, and applied to the emissions savings as demonstrated in Table 4.7.

Table 4.7: Emissions Benefit per Incident

Pollutant	Savings (g/Incident)	Savings (Tons/Incident)	Emissions Cost ($/Ton)	**Emissions Benefit ($/Incident)**
THC	975.78	0.00107	2,529.30	**$2.72**
VOC	912.64	0.00101	2,181.15	**$2.19**
CO	5,591.10	0.00616	5,544.78	**$34.14**
NOX	737.49	0.00081	5,319.51	**$4.32**
PM	-69.96	-0.00008	4,362.31	**-$0.34**

These average benefits can then be summed to calculate the total pollution benefit from implementing quick clearance legislation.

$2.72 + $2.19 + $32.14 + $4.32 + (-$0.34) = $43.04 per incident

Thus, for an average minor incident at the Greenville site, implementing quick clearance legislation can save **$43** per incident for the 100% compliance scenario. Table 4.8 shows emissions benefits for different percentages of drivers complying with the law.

Fuel consumption benefits were calculated similarly to the emissions benefits above, with the exception of the units used. PARAMICS outputs give a measure of fuel consumption in gallons, and fuel prices are generally thought of in terms of dollars per gallon ($/gal). This made the benefit conversion simple, as displayed in Table 4.9. Table 4.10 demonstrates the fuel consumption benefits possible for scenarios in which less than 100% of drivers follow the law's stipulations.

Table 4.8: Emissions Benefit per Incident Due to Law

	Emissions Savings Benefit by Percent Compliance			
Percent of Drivers Compliant (%)	100%	75%	50%	25%
Total Hydrocarbons Savings ($)	$2.72	$2.04	$1.36	$0.68
Volatile Organic Compounds Savings ($)	$2.19	$1.64	$1.10	$0.55
Carbon Monoxide Savings ($)	$34.14	$25.61	$17.07	$8.54
Nitrous Oxides Savings ($)	$4.32	$3.24	$2.16	$1.08
Particulate Matter Savings ($)	-$0.34	-$0.25	-$0.17	-$0.08
Total Dollar Benefit of Emissions ($)	**$43**	**$32**	**$22**	**$11**

Table 4.9: Fuel Consumption Benefits per Incident

Type of Fuel	Savings (gal/Incident)	Fuel Cost ($/gallon)	**Fuel Consumption Benefits ($/Incident)**
Gas	15.70	$2.485	**$39.02**
Diesel	-4.52	$2.816	**-$12.73**

Table 4.10: Fuel Consumption Benefits per Incident Due to Law

	Fuel Consumption Benefit by Percent Compliance			
Percent of Drivers Compliant (%)	100%	75%	50%	25%
Unleaded Gasoline Savings ($)	$39.02	$29.26	$19.51	$9.75
Diesel Savings ($)	-$12.73	-$9.55	-$6.36	-$3.18
Total Benefit of Fuel Consumption ($)	**$26**	**$20**	**$13**	**$7**

In this analysis, fuel costs were estimated based on current fuel averages at the time of the study. The negative benefit for diesel fuel gives a resulting fuel consumption benefit that is somewhat less than anticipated, although still a positive benefit. As seen in Table 4.10, the overall fuel consumption benefit therefore is approximately **$26** for the

100% scenario, and decreasing values for the lower percentages of driver compliance with the law. Combining the $26 fuel consumption benefit with the $43 emissions benefit gives a result of **$69** in environmental benefits, in terms of dollars per incident. The fuel consumption benefit was $17, $35, and $52 for the 25%, 50% and 75% compliance scenarios, respectively.

Costs of Incident Clearance Legislation

The implementation costs of the "Steer It Clear It" law in South Carolina involve advertising costs to make sure drivers are aware of this policy change. Even obtaining a rough estimation of the implementation cost proved difficult. Advertising costs were estimated by considering signage and billboard advertisements on the freeway as well as radio and TV commercials. Both the radio and the TV commercials were assumed to be produced by the DOT, making costs considerably lower, as would be expected for this type of situation. The radio advertisement would be a 60-second commercial run locally once per week of the first year of the law, while the TV spot cost corresponds to local advertisement for one week. The cost estimations for both of these media types were found by researching various advertising companies and radio and TV stations.

Billboard signage on the freeway was considered as well, and values for this sign were determined by finding the cost involved in producing the image as well as rental of the billboard for one year. Other signs specific to the law would also be produced, as is South Carolina's current practice. The costs of these signs were found by estimating capital and maintenance costs for both the sign and the breakaway post, as well as costs of labor for installation. These signs were assumed to be spaced at 5 miles on each side of the freeway for all 52 miles of Greenville County's interstate highways. The total cost for advertising and implementing at the Greenville site was estimated at **$11,614** per year for the first year of implementation. This study did not consider legislative expenditures due to the unknown cost of passing legislation. A summary of the costs assumed is shown in Table 4.11.

Table 4.11: Estimated Costs of "Steer It and Clear It" Legislation per Year

	Freeway Signs, Installation and Posts	Billboard	Radio	TV	Total
Costs Include:	5-mile spacing per sign, each direction	One sign; produce image + monthly rent	60-second ad, run once per week	Airing locally for one week	–
Costs ($/year)	$4,308	$46	$4,160	$3,100	**$11,614**

Benefit-Cost Ratio

Because the costs values are expressed in terms of dollars per year, the benefits data must be converted into a yearly benefit. Based on historical incident data for the Greenville site, this research found that approximately 722 incidents could be affected by quick clearance legislation in one year's time. Using this information, calculating a yearly delay savings benefit of the law proceeds as follows:

$803 per Incident × 722 Incidents per year = $579,766 per year

This delay savings applies exclusively to the Greenville site, although similar areas may yield similar results. For urban areas outside of South Carolina, with more traffic on the roadways, the benefits can be much greater. The savings may then be passed on to employers and manufacturers, who in turn can forward them to workers and consumers. In addition, implementing this incident clearance legislation gives an environmental benefit of $69 per incident. Converting the environmental benefit value to a yearly benefit then becomes:

\$69 per Incident × 722 Incidents per year = \$49,818 per year

The total benefit per year is then simply a sum of the delay benefit and the environmental benefit, which is equal to **$629,584** per year. The next step of the analysis is to divide the total benefit by the total cost, giving the resulting benefit-cost ratio, as shown below.

\$629,584 ÷ \$11,614 = 54.2

Because the costs for the quick clearance legislation are so minimal, the benefit-cost ratio is an exceptionally high value. In most situations such a benefit-cost ratio would be considered incorrect, and not to be truly representative of actual conditions. However, the costs of the "Steer It Clear It" law are very low by nature, because it does not require the installation of any electronic signs or communication lines, like many other incident management programs. There are no additional infrastructure costs other than costs associated with signs for advertisement of and information about the law. In addition, once drivers become familiar with the law, the need for advertising will steadily decrease, leading the benefit-cost ratio to increase beyond this value in future years.

Table 4.12: Benefit-Cost Ratio for Law by Percent Compliance

Percent of Drivers Compliant (%)	100%	75%	50%	25%
Total Yearly Benefit ($)	$629,584	$472,910	$315,514	$157,396
Total Benefit-Cost Ratio	**54.2**	**40.7**	**27.2**	**13.6**

Furthermore, the benefit-cost ratios for each of the driver compliance categories are shown in Table 4.12. These values likely approximate more realistic scenarios in which less than 100% of drivers fully comply with the law.

CHAPTER FIVE
CONCLUSIONS

The objective of the research project was to quantify the advantages of reduced incident durations through the "Steer It and Clear It" in terms of reduced incident-related delays, emissions, and fuel consumption. Using the microscopic simulation software PARAMICS, a comparison of the mean vehicle-hours of travel (VHT) of the "before law" and "after law" conditions was conducted. Statistical analysis of the results indicated that the two means are significantly different.

The study found that the impact of this legislation consisted of reduced average traffic delays of 52 vehicle-hours at the study site for situations where drivers comply fully with the law. This reduced delay results in an average cost savings of $803 per incident, which is substantial when considering the number of incidents occurring on a daily basis in large metropolitan areas. The reduced delay also demonstrates that reducing the first three components of incident duration; the detection and verification, response, and clearance phases, positively influences the recovery phase. This effect is due to the nature of traffic operations, where increased traffic delay results in exponential increases of the amount of time necessary for returning the roadway to normal conditions. In addition to reduced delay, fuel consumption decreased and emissions were reduced after implementation of the quick clearance legislation studied in these simulations. These benefits added up to $69 per incident, which is additional to the calculated delay savings of $803 per incident. The total dollar benefit per incident, when considering delay savings and environmental benefits, is therefore $872 per incident. Taking into account the 722 incidents each year that could be affected by the law, the yearly benefit is approximately $630,000, resulting in a final benefit-cost ratio of 54.2:1. For a scenario in which 75% of drivers comply with the law, the benefit-cost ratio will be 40.7:1, and if only 25% of drivers comply, the benefit for every $1 spent on implementing the law would be as low as $13.60. The delay savings found in this research for 100% compliance amounts to 0.53% of the VHT for the "before" condition for a minor crash, and 0.40% for 75% compliance. This benefit-cost analysis presents a strong case for implementation of quick clearance legislation.

Future Research

The benefit-cost ratio determined in this study provides opportunities for future research on the subject. First, the true benefits of the law need to be quantified in monetary terms, with full detailed inclusion of all the costs of traffic congestion. Agencies implementing the law can also keep track of expenditures related to advertisements and any other methods of informing the public of the terms of the legislation. At the time of this research, certain advertising costs were assumed due to the inability to obtain accurate numbers from the public agencies. In addition, a full implementation cost analysis should be conducted to determine the actual cost of passing such legislation through all branches of state government. Such analysis was attempted in this research, but due to the lack of historical data and records available, this research relied on assumptions that have not yet been verified for accuracy.

Reductions in emissions and fuel consumption were determined from this research, but with some limitations of the data obtained. Future projects should incorporate the full effects of accelerations and decelerations of stop-and-go traffic. Idling speeds of 0 miles per hour should also be integrated into the analysis as well so that the effect of quick clearance legislation on the numbers of vehicles stopped in traffic can be clearly demonstrated.

The full effects of "Move-It" or "Steer It and Clear It" laws include more qualitative factors, such as safety improvements, in addition to reduced delay and emissions. To show the true benefits of driver removal laws, studying the effects of the law over time is essential. A small sampling of the effects of such a removal law might include reductions in secondary incidents and reductions in responder fatalities resulting from struck-by accidents. These safety concerns are directly related to incident duration, and therefore could be significantly impacted by driver removal legislation. The author was hopeful in devising a way to demonstrate these effects using simulation but ultimately decided that data was insufficient to develop such a process at this time. The most effective way to measure these impacts will be to track all these parameters continually, such as statistics on the number of secondary crashes, with a reliable and consistent way of recording the data so that it can be used by future researchers.

Reduced traffic congestion would also lead to other enhancements in the quality of life of motorists, benefits that are difficult to quantify but distinctly perceived by road users. In addition to the collection of before and after data and improved fuel consumption and emissions analysis, studies such as this one should be continuously reviewed and updated to ensure that these benefits to the public would be of lasting consequence.

APPENDICES

Appendix A

Data Outputs

Before Law:									
Lanes Blocked	**Incident Duration**	**Vehicle Hours of Travel (VHT)**	**Fuel-Gas (FCG)**	**Total Hydrocarbons (THC)**	**Volital Organic Compounds (VOC)**	**Carbon Monoxide (CO)**	**Nitrous Oxide (NOX)**	**Particulate Matter (PM)**	**Fuel-Diesel (FCD)**
1	808	9811.06	5417.202	41263.9	37618.5	368693.8	175678.2	35850.4	2687.5
2	1052	9753.09	5450.575	41394.6	37719.5	380633.8	172267.3	35464.1	2611.9
3	994	9845.61	5397.149	41021.8	37208.4	377560.6	173812.3	35568.3	2655.3
4	973	9873.54	5412.698	41163	37612.1	378151.6	171693.1	35222.2	2602.4
5	979	9765.59	5405.612	40842.2	37216	377097.9	170893.4	35051.9	2585.5
6	939	9760.14	5416.331	41226	37673.8	368702.8	173776.2	35547.8	2644.2
7	833	9833.16	5443.98	41358	37780.8	370409.9	171983.7	35322.2	2598.9
8	957	9789.21	5407.991	41077.5	37425.9	369701.7	171264.6	35202.6	2593.6
9	1041	9813.96	5418.313	41780.8	37627.5	377173.8	173979.9	35629.7	2649.5
10	988	9771.35	5475.292	41437.1	37756.4	378242.3	172914.5	35532.7	2617.9
11	923	9761.04	5412.276	41082.8	37437.4	372741.9	171613.3	35163	2596.8
12	1018	9782.65	5427.831	41247.3	37797.5	375938.4	171607.6	35309.4	2601.7
13	868	9780.72	5423.99	40934.3	37291.8	367280	170548.3	35070.3	2577.7
14	923	9813.41	5398.483	41142.2	37499.4	375646.6	172179.8	35213.9	2612.2
15	998	9838.03	5392.493	40677.2	37463.9	374697.3	169573	34865.1	2563.7
16	862	9844.31	5389.481	41066.6	37427	367329.3	173582.2	35581.9	2649.8
17	917	9764.83	5449.054	41050.3	37400.2	373300.2	171339	35262.9	2593.6
18	859	9749.18	5424.718	40977.8	37152.5	366052.5	170962.8	35252.7	2597.9
19	1013	9745.34	5449.745	41097.3	37676.4	375953.9	171118.1	35271.2	2592
20	808	9793.45	5417.776	41203.7	37550.4	368698.4	173699.8	35543.5	2643.5
21	905	9793.46	5413.67	41342.5	37417.3	368215	171182.5	35109.6	2582.1
22	838	9753.09	5430.129	40843.4	37211.6	366584.8	170761.9	35193	2590
23	950	9845.61	5474.11	41336.1	37865.9	376469.8	173097.2	35502	2621.8
24	947	9873.54	5470.577	41521.3	37837.9	376737.8	174046.9	35583	2634.8
25	1052	9765.59	5423.179	41589	38145.6	38150.79	173958.6	35147.7	2587
26	1052	9760.14	5398.106	41699.4	38063	380585.8	174194.6	35248.3	2600.2
27	866	9833.16	5426.49	41222.5	37970.6	368954.7	174863.1	35805.8	2668.8
28	901	9789.21	5431.32	40982.5	37335.7	373687.5	171242.7	35286.1	2596.4
29	880	9813.96	5407.195	41238.7	37572	369112.1	172012.5	35319.2	2607.7
30	920	9771.35	5430.427	40953	37459.4	374501.6	170839.8	35147.4	2585.2
31	838	9761.04	5400.435	40851.9	37225.7	366043.6	172450.4	35466.3	2629.1
32	956	9782.65	5411.528	41057.1	37818.7	377427.8	173320.6	35539.1	2640.6
33	888	9780.72	5415.747	41046.3	37405.1	367683.1	173156.8	35405.6	2631.3
34	934	9813.41	5444.831	41387	37720.4	375057.7	172939.3	35362.2	2616.3
35	877	9838.03	5417.072	41275	37617.8	369230.2	175113.5	35771.8	2670.5
36	944	9844.31	5499.894	41249.1	37563.5	375871.2	168666.5	34966.4	2527.9
37	1017	9764.83	5382.488	41411.3	38003.3	379301.5	173651.2	35452.1	2644.5
38	953	9749.18	5396.804	40870.3	37249.5	375882.7	173287.5	35545.4	2648.2
39	853	9745.34	5382.957	41993.6	38301.7	371679.4	171990.4	34963.1	2594.2
40	995	9793.45	5462.17	41074.9	37419	376664.5	170317.9	35077.8	2565.7

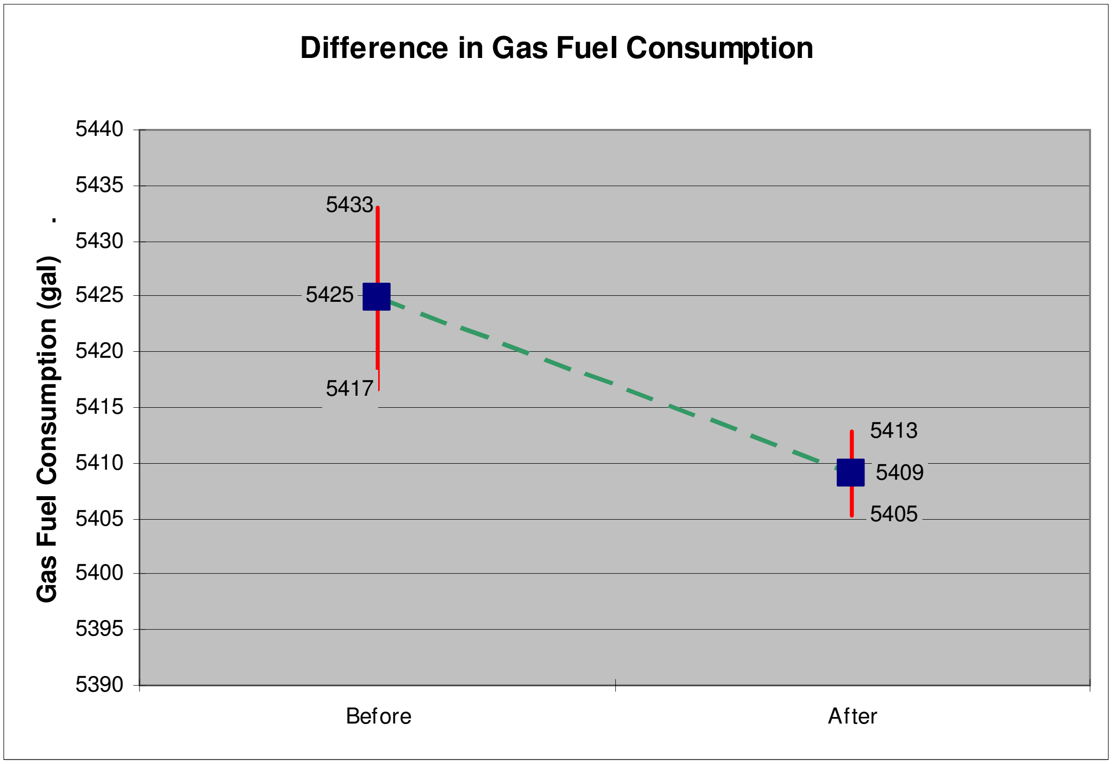
Before Law (continued):									
Lanes Blocked	**Incident Duration**	**Vehicle Hours of Travel (VHT)**	**Fuel-Gas (FCG)**	**Total Hydrocarbons (THC)**	**Volital Organic Compounds (VOC)**	**Carbon Monoxide (CO)**	**Nitrous Oxide (NOX)**	**Particulate Matter (PM)**	**Fuel-Diesel (FCD)**
41	1011	9752.58	5395.458	40818.6	37493	378999.1	172300.3	35347	2622.2
42	1003	9814.25	5429.339	41170.4	37522.6	377604.2	174045.2	35663.9	2651.4
43	808	9812.27	5452.536	41268.7	37604.5	369665.1	171821.9	35293.5	2598.4
44	948	9870.11	5453.551	41475.6	37803.4	379063.6	175647.9	35890.6	2679.6
45	930	9826.29	5434.226	41214.4	37563.8	376909.5	174698.3	35804.2	2669.2
46	991	9771.13	5417.461	41120.2	37978.8	377736.2	172786	35403.9	2626
47	902	9720.4	5371.513	40636.1	37023.5	375812	170999	35186.6	2598.8
48	874	9734.32	5404.73	40761	37136.5	365735.4	170648.2	35125.4	2588.5
49	867	9788.99	5407.327	41144.7	37493.8	368122.3	172259.2	35399.4	2617.6
50	953	9731.16	5341.307	41295.7	37278.1	376874.3	172879.6	35351.5	2635.8
51	860	9829.78	5440.429	41434.3	37777.2	370028.7	176093	35914	2694
52	1028	9727.65	5381.544	41834.6	38015.9	386442.3	174188	35306.9	2621
53	960	9713.3	5346.801	40950.9	37554.3	374145.3	175236.4	35745.4	2695.4
54	981	9720.15	5415.78	40856.8	37235.1	372055.4	171331.9	35124	2597.3
55	846	11714.59	5842.634	83979	77707.1	605172.2	221360.5	34402.5	2803.8
56	925	9753.62	5369.892	40893.9	37255.9	370271.1	170935.5	35102.1	2589
57	909	9692.44	5358.004	40810.4	37202.1	365190.8	172527	35339.2	2637.4
58	929	9741.75	5385.048	40883.7	37253.9	366161.1	171764.5	35220.8	2610.1
59	1052	9923.46	5430.703	41235.8	37583.2	380051.7	174535.8	35708.6	2662.6
60	875	9824.39	5460.61	41374.1	37717.8	369961.9	174588.9	35723	2603.7
61	1015	9868.18	5383.479	41111.3	37477.4	377301.5	174162.5	35467.3	2670.8
62	951	9746.34	5394.146	41009.4	37752.8	376001.6	173295.5	35588	2649.2
63	860	9753.45	5379.89	41983.5	38310.5	371681.1	170057.7	34969.3	2573
64	997	9832.58	5462.75	41007.2	37613.6	375676.5	170319.3	35150.4	2578.9
65	1010	9840.09	5391.392	41725	37493	376006.3	172326	35653.9	2645.9
66	1002	9813.37	5431.004	41668.3	37518.4	378609.3	174145.2	35666.2	2667.3
67	808	9850.11	5453.636	41871.9	37809	369675.9	171827.3	35320.6	2592.1
68	947	9826.29	5457.001	41475	37813.7	371059.2	175649.4	35942.6	2628.3
69	931	9801.67	5437.942	41220.6	37564.7	374914.1	174688	35435.8	2678.6
70	1000	9921.14	5417.461	41459.3	37973.4	374745.8	173471	35456.9	2649.6
71	876	9734.32	5371.513	40989.3	37319.6	364415.8	171180.7	35175	2559.3
72	875	9788.99	5413.76	41754.4	37439.9	365782.4	170648.2	35100.3	2596
73	866	9731.16	5407.327	41949.6	37460.8	368122.3	172301.3	35170.1	2630.6
74	954	9829.78	5465.278	41495.7	37688	371956.3	172916.3	35336.1	2635.8
75	855	9727.65	5442.436	41434.3	37789.6	370778.7	176179.7	35105.8	2650.9
76	1020	9930.65	5488.18	41836	37924.8	375992.3	172199.7	35293.7	2621
avg	933	9819	5425	41804	38114	371850	173310	35365	2623

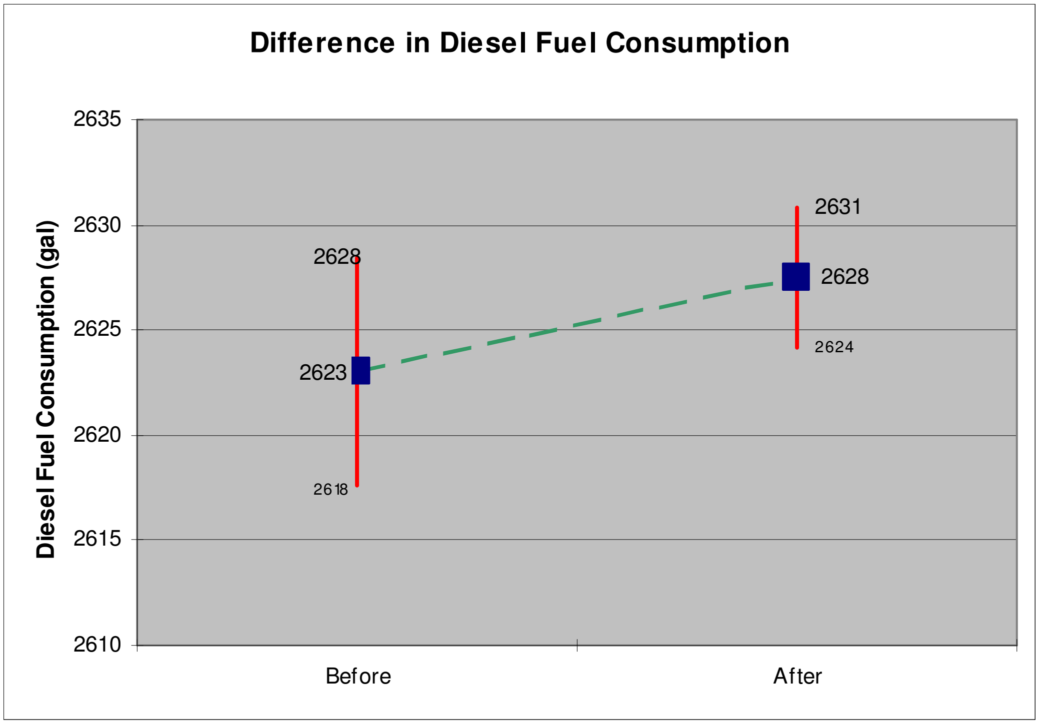
After Law:									
Lanes Blocked	Incident Duration	Vehicle Hours of Travel (VHT)	Fuel-Gas (FCG)	Total Hydrocarbons (THC)	Volital Organic Compounds (VOC)	Carbon Monoxide (CO)	Nitrous Oxide (NOX)	Particulate Matter (PM)	Fuel-Diesel (FCD)
1	413	9771.89	5421.285	40907.8	37276.1	366865.2	172633.5	35416.9	2625.9
2	412	9818.38	5416.467	41073.6	37425.4	368182.4	173664.2	35621.6	2646.4
3	263	9746.65	5391.368	40733.3	37114.5	365342	171886.9	35349.9	2616.6
4	306	9789.37	5412.882	40881.1	37244.4	366986.2	172374.2	35412.5	2620.9
5	401	9679.66	5354.571	40365.1	36783.9	362211	172264.4	35337.6	2633.9
6	377	9731.62	5410.793	40630.2	37026.5	364746	172810.8	35420	2633.9
7	330	9823.11	5455.64	41063.1	37432	368236	176475.3	36016.5	2704.7
8	441	9791.25	5450.312	41011	37367.1	368025.3	172111.9	35375	2612
9	345	9702.36	5369.974	40545.4	36941.6	363792.1	170917.8	35129.9	2598
10	372	9800.8	5434.221	40988	37343.2	367963.2	172335.5	35386.1	2614.3
11	238	9828.26	5461.273	41079	37429	368761.7	173148.9	35566.8	2629.5
12	385	9728.09	5381.543	40525.7	36917.1	364166	171006.8	35209.6	2600.2
13	333	9772.86	5427.91	40814.4	37178.8	366723.3	170742.2	35170.2	2583
14	314	9712.09	5371.126	40455.4	36859.6	363329.1	171848.4	35368	2626.3
15	281	9732.09	5403.863	40582.1	36970.7	364716.5	171005.9	35229.5	2599.5
16	339	9721.42	5379.651	40610.7	37001.6	364378	171329.8	35211.2	2604.4
17	238	9718.19	5404.397	40385.8	36786.8	363553.4	170252.6	35151.7	2584.3
18	425	9719.41	5379.56	40518	36924.5	363573.4	173278.2	35515.5	2650.6
19	397	9815.11	5414.968	41128.4	37482	368337.3	174494.5	35712.8	2664.6
20	398	9806.02	5453.972	41014.8	37370.3	368183.5	172726.7	35449	2621.2
21	346	9763.42	5429.463	40977.1	37344.3	367195.4	172675.9	35396.6	2626.3
22	382	9748.26	5396.7	40679.9	37063.2	365211.8	171817.1	35344.3	2614.7
23	383	9769.03	5400.72	40714.5	37093.2	365609.3	172413.8	35511.3	2631.8
24	303	9758	5421.579	40780.9	37153.7	366240.2	171607.1	35268.1	2605.3
25	397	9785.22	5383.369	40843.6	37218.5	365936.8	173801.8	35719.8	2660.7
26	400	9725.24	5399.964	40539.8	36929.7	364553.8	170546	35103.9	2586.5
27	249	9797.29	5417.956	40893.8	37263.9	366870.8	173890.1	35693.4	2656.3
28	407	9816.85	5445.568	41050.7	37401.8	368511.3	173026.9	35504.8	2628.6
29	361	9806.57	5391.777	40986.8	37343	367202.4	173083.8	35611.9	2641.1
30	312	9727.76	5362.73	40587	36992	363791.1	174327.3	35700.4	2677.4
31	362	9811.08	5418.018	42746.3	38999.9	376398.2	171936.7	34906.6	2571.4
32	385	9740.49	5380.689	40712.6	37098.7	365054.3	172728	35426.8	2635.6
33	355	9746.96	5413.722	40609.6	36996.5	365061.9	171588	35297.4	2606.7
34	482	9772.46	5427.302	40862.5	37222.9	367043.7	170599.6	35185.7	2585.1
35	337	9808.87	5451.688	40900.4	37253.5	367779.7	170877.4	35294.1	2586.3
36	238	9699.98	5356.128	40492.2	36896.6	363209.9	171978.6	35368.5	2631.7
37	262	9765.7	5415.371	40821.6	37204	366057.3	173980	35618.1	2657
38	317	9821.45	5453.359	41022.8	37373.9	368384.8	172544.4	35486	2617.5
39	337	9697.01	5355.633	40440.8	36857.7	362516.2	173579.9	35546.8	2661.9
40	335	9758.1	5382.9	40878.6	37254.3	366121.1	173517.8	35495.4	2648.2

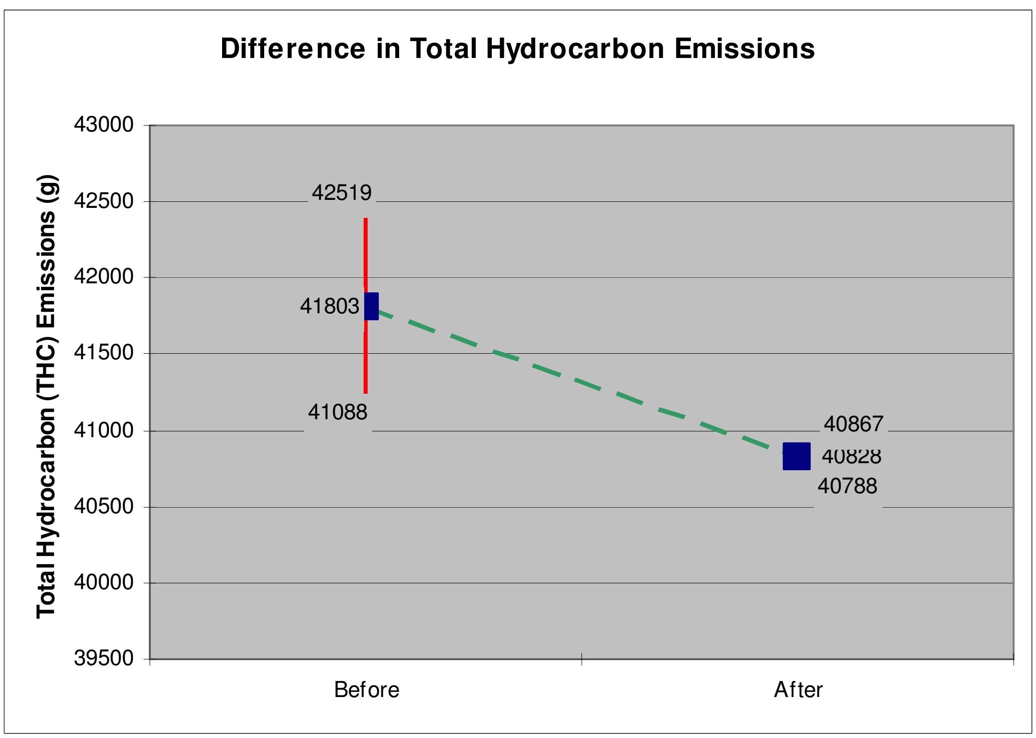
After Law (continued):									
Lanes Blocked	**Incident Duration**	**Vehicle Hours of Travel (VHT)**	**Fuel-Gas (FCG)**	**Total Hydrocarbons (THC)**	**Volital Organic Compounds (VOC)**	**Carbon Monoxide (CO)**	**Nitrous Oxide (NOX)**	**Particulate Matter (PM)**	**Fuel-Diesel (FCD)**
41	329	9766.78	5417.745	40841.1	37212.5	366509.8	172310.5	35346.3	2617.5
42	461	9760.45	5399.605	40822.2	37211.2	365654	175099.2	35750.3	2681.3
43	335	9851.16	5459.977	41170.9	37511	369594.9	173804.6	35651.4	2641.7
44	282	9809.86	5424.025	40989.7	37343.3	367844.1	172333.4	35434.1	2615.5
45	342	9676.81	5368.623	40375.3	36785.7	362581.2	170451.7	35063.7	2590.5
46	254	9783.45	5426.314	40941.9	37306.7	367277.2	172853.6	35414.1	2625.6
47	305	9735.53	5415.592	40726.6	37105.1	365719.4	170891	35147.4	2592.3
48	419	9831.22	5418.696	41191.1	37543.8	368590.9	175652.4	35953.3	2691.4
49	339	9668.21	5361.828	40410	36829.8	362460.3	172464.3	35290.8	2636
50	341	9788	5419.447	40892.3	37257.3	366894.7	172390.6	35522.6	2627.4
51	268	9747.26	5409.135	40658.2	37039.7	365458	171369.1	35212.8	2601
52	445	9761.89	5397.446	40708	37088.8	365502	172372.9	35455.6	2627.7
53	390	9744.55	5394.768	40761.1	37138.8	365596.6	171781.9	35306.3	2614
54	401	9724.9	5372.911	40606.4	37001.7	364146.6	172219.3	35395.9	2627.9
55	314	9787.65	5437.045	40954.6	37315.6	367605.2	172188.7	35351.5	2610.7
56	472	9720.27	5378.258	40557.3	36956	363893.2	172242.4	35399.9	2629.2
57	276	9783.75	5415.676	40839.5	37207.7	366670.6	172571.7	35432.6	2624.9
58	437	9795.14	5434.807	40806.6	37172.4	366907.6	172078.7	35430.1	2615.3
59	402	9820.86	5460.577	41139.1	37479	369287	171819.7	35384.1	2604.2
60	362	9692.83	5362.959	40499.9	36901.7	363327.3	171077.3	35193.2	2607.5
61	339	9787.6	5427.192	40955	37323.5	367277.4	173689.8	35622.2	2650.8
62	342	9846.19	5458.73	41210.6	37555.4	369556.4	174406.8	35680.1	2649.1
63	429	9796.02	5416.256	40879.8	37244.3	366895.1	172792.3	35533.8	2631.9
64	311	9798.29	5434.782	40961.3	37319	367818.9	172462.2	35411.4	2619.3
65	412	9715.03	5358.011	40621.6	37026.3	363743	174287.8	35609.4	2673.1
66	419	9730.08	5360.827	40751.5	37142.2	364780.9	173657.9	35524.2	2656.9
67	419	9766.33	5416.665	40761.9	37131.6	366328.1	171026.9	35265.5	2597.3
68	364	9716.9	5378.756	40596.7	36999.3	364071.6	173626.9	35492	2655.6
69	297	9781.27	5419.75	40860.1	37229.5	366644.6	172444.8	35505.5	2626.8
70	380	9932.15	5451.283	41593.2	37903.6	372637.2	175911	36102.2	2681.3
71	475	9721.49	5381.956	40566	36955	363012.3	172249.7	35410.5	2631.8
72	302	9779.03	5409.044	40856.4	37216	366473.6	171579.2	35241.9	2600.8
73	348	9695.39	5366.394	40495.6	36909.5	363345.2	171765.9	35187.2	2609.2
74	341	9738.02	5433.005	40881.1	37265.6	367279.5	173686.1	35645.1	2662.9
75	355	9842.57	5464.878	41174.8	37519.5	369599.3	173810.3	35654.9	2646.9
76	308	9822.05	5439.47	40992.5	37343.9	367841.1	172346.7	35467.3	2615.3
avg	355	9766	5409	40828	37202	366259	172573	35434	2628

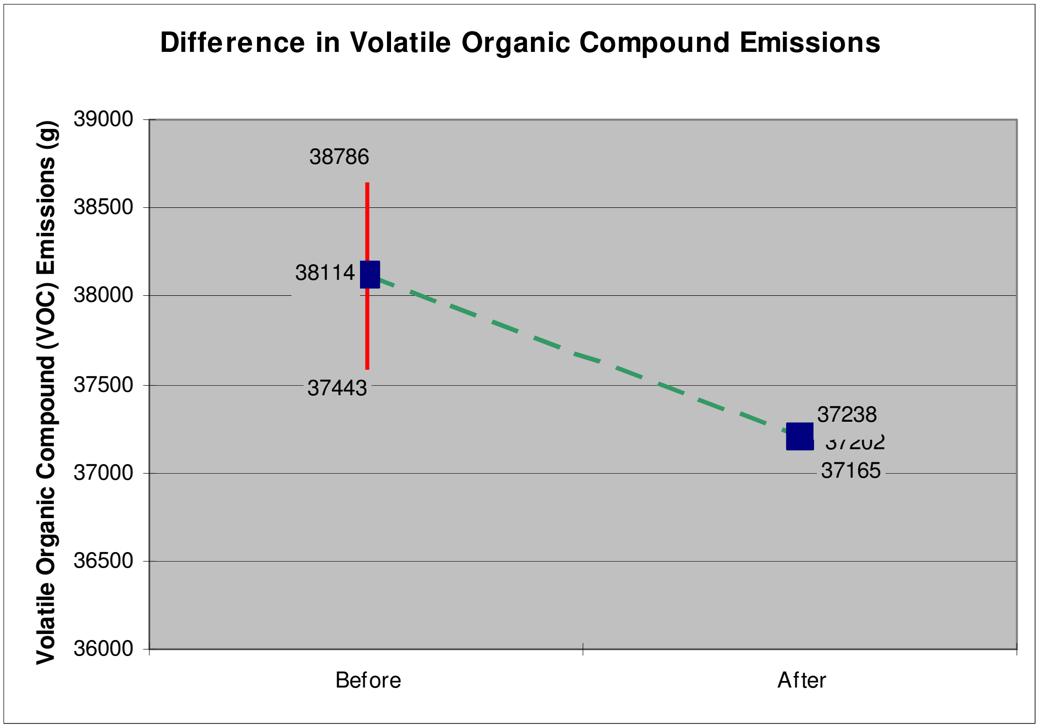
Appendix B

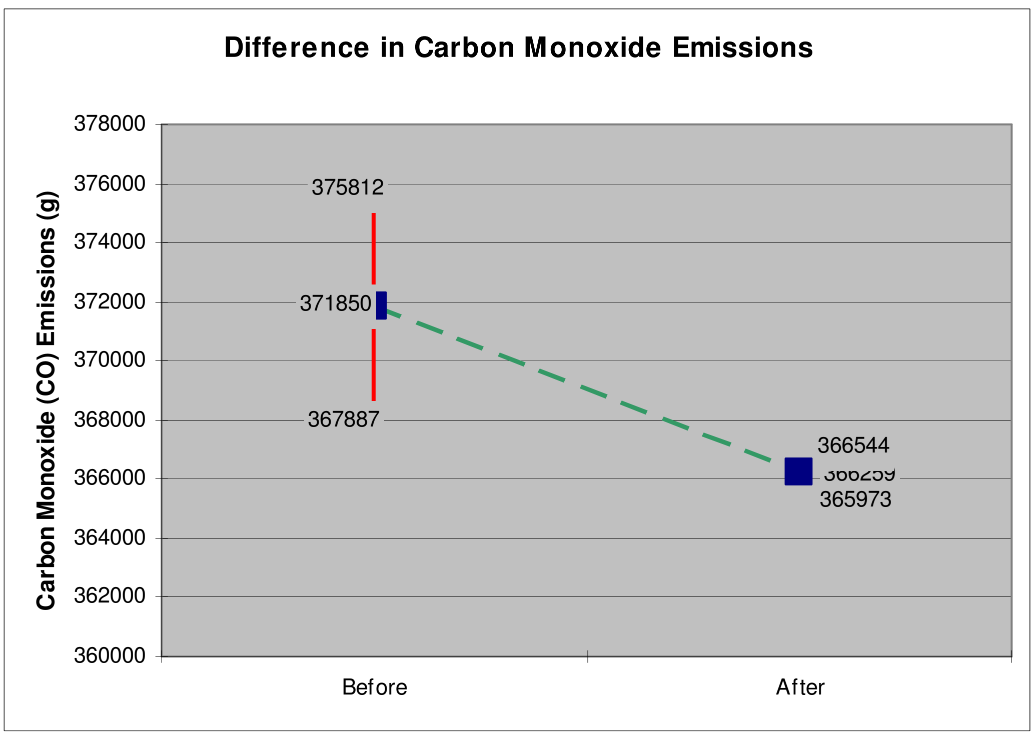
Graphs and Figures

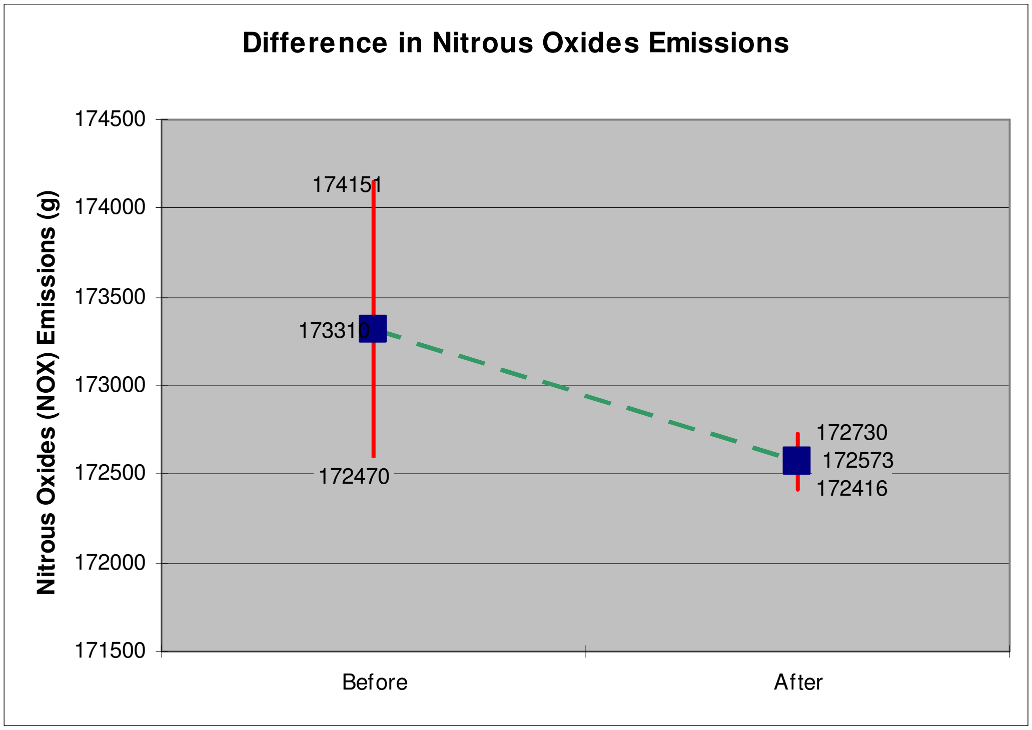


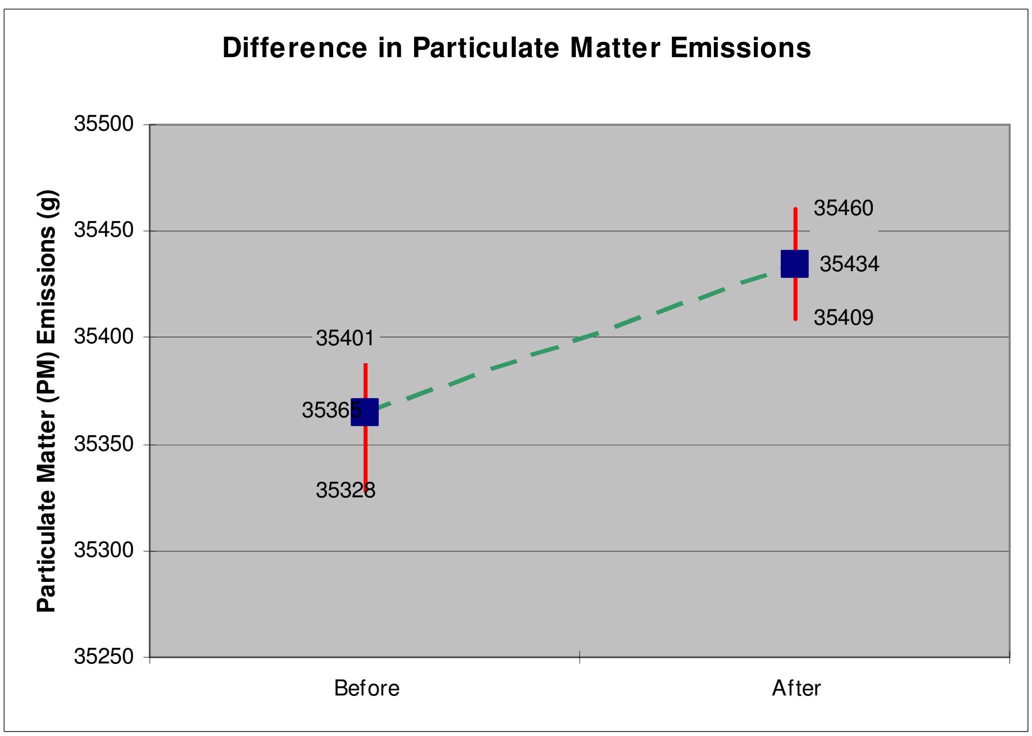

Difference in Diesel Fuel Consumption
Diesel Fuel Consumption (gal)
2635
2630
2625
2620
2615
2610
2628
2623
2618
2631
2628
2624
Before
After

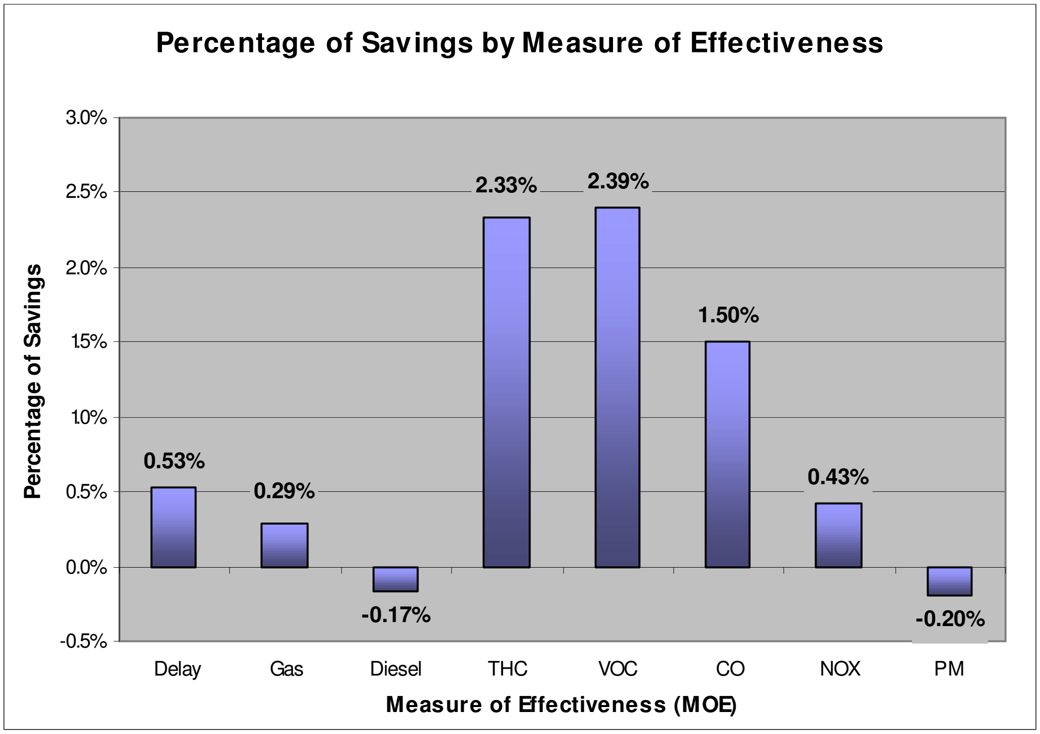

Difference in Total Hydrocarbon Emissions
Total Hydrocarbon (THC) Emissions (g)
43000
42500
42000
41500
41000
40500
40000
39500
42519
41803
41088
40867
40828
40788
Before
After


Difference in Volatile Organic Compound Emissions
Volatile Organic Compound (VOC) Emissions (g)
39000
38500
38000
37500
37000
36500
36000
38786
38114
37443
37238
37165
Before
After


Difference in Carbon Monoxide Emissions
Carbon Monoxide (CO) Emissions (g)
378000
376000
374000
372000
370000
368000
366000
364000
362000
360000
375812
371850
367887
366544
365973
Before
After


Difference in Nitrous Oxides Emissions
Nitrous Oxides (NOX) Emissions (g)
174500
174000
173500
173000
172500
172000
171500
174151
173310
172470
172730
172573
172416
Before
After


Difference in Particulate Matter Emissions
Particulate Matter (PM) Emissions (g)
35500
35450
35400
35350
35300
35250
35401
35365
35328
35460
35434
35409
Before
After


Percentage of Savings by Measure of Effectiveness
Percentage of Savings
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
-0.5%
0.53%
0.29%
-0.17%
2.33%
2.39%
1.50%
0.43%
-0.20%
Delay
Gas
Diesel
THC
VOC
CO
NOX
PM
Measure of Effectiveness (MOE)

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