1. Report No. SWUTC/13/600451-00103-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Effect of Changing Driving Conditions on Driver Behavior Towards Design of a Safe and Efficient Traffic System		5. Report Date December 2013 6. Performing Organization Code
7. Author(s) Fereydoun Aghazadeh, Laura Hughes Ikuma and Sherif Ishak		8. Performing Organization Report No. Report 600451-00103-1
9. Performing Organization Name and Address Gulf Coast Center for Evacuation and Transportation Resiliency Department of Civil and Environmental Engineering Louisiana State University Baton Rouge, LA 70803		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTRT12-G-UTC06
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas A&M Transportation Institute Texas A&M University System College Station, Texas 77843-3135		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes Supported by a grant from the U.S. Department of Transportation, University Transportation Centers Program.		

16. Abstract

This simulation-based study explores the effects of different work zone configurations, varying distances between traffic signs, traffic density and individual differences on drivers' behavior. Conventional Lane Merge (CLM) and Joint Lane Merge (JLM) were modeled in a driving simulator and thirty participants (seven female and 23 male students) navigated through the two configurations with two levels of traffic density and in three different conditions: *a)* standard sign distance, *b)* 25% reduction, and *c)* 25% increase in the distance between traffic signs in the advance warning zone. Information regarding travel time, speed, braking force and location of merge was collected through the simulator. Self-reported measures of mental demand, physical demand, temporal demand, performance, effort, frustration and total workload were recorded from all participants by using the NASA TLX. The results show that, on average, driving through the JLM took 18.8% longer than the CLM. Moreover, no significant difference in speed was found between the two merge configurations. However, the percent maximum braking force was34% lower in the JLM configuration. The comparison of two merge configurations with respect to the location of changing lanes suggest that overall, the JLM configuration encourages drivers to remain in the closed lane longer. The analysis of self-reported workload ratings shows that participants reported 15.3% lower total workload and 18.8% higher performance when driving through the JLM. Moreover, mental demand, temporal demand, effort and frustration were lower in JLM by 16.4%, 23.4%, 13.7% and 28%, respectively. In terms of self-reported workload, the JLM is more conducive to driving. In conclusion, the JLM outperforms the CLM.

17. Key Words	18. Distribution Statement
Work Zone, Joint Merge Configuration, Driver Behavior	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	69	

EFFECT OF CHANGING DRIVING CONDITIONS ON DRIVER BEHAVIOR TOWARDS DESIGN OF A SAFE AND EFFICIENT TRAFFIC SYSTEM

by

FEREYDOUN AGHAZADEH

LAURA HUGHES IKUMA

AND

SHERIF ISHAK

RESEARCH REPORT SWUTC/13/600451-00103-1

GULF COAST CENTER FOR EVACUATION AND TRANSPORTATION RESILIENCY
Louisiana State University
Baton Rouge, La70803

December 2013

Executive Summary

Over the past decade, several alternative merging configurations have been proposed and tested over conventional lane merge (CLM). This research investigates the efficiency of an alternative merging strategy known as Joint Lane Merge (JLM) in terms of its effects on drivers' behavior and traffic flow characteristics by using a full-size driving simulator combined with human factors analysis techniques. The objectives of this study are: 1) to determine the effects of work zone configuration, traffic flow levels and the distance between traffic signs on driver behavior, 2) to determine the effect of individual differences on driving behavior, and 3) to demonstrate the use of human factors analysis techniques applied to the understanding of driver behavior and performance in high way work zones.

Twelve work zone configurations were modeled by using a driving simulator based on two merge layouts (CLM and JLM), two levels of traffic density (high or low) and three levels of distance between traffic signs (standard, 25% increase and 25% decrease).The dependent variables were travel time (s), average speed (mph), percent maximum braking force (%), location of changing lane (ft) and drivers' perceived workload (%).Information regarding gender, personality type, years of driving experience, previous traffic offense and aggressiveness was collected through questionnaires and was considered as modifiers of drivers' behavior in work zones.

The results show that, on average, driving through the JLM took 18.8% longer than the CLM. No significant differences in speed were found between the two merge configurations. However, the mean maximum braking forces was 34% lower in the JLM configuration. The comparison of two merge configurations with respect to the location of changing lanes suggest that overall, the JLM configuration encourages drivers to remain in the closed lane longer. The analysis of self-reported workload ratings shows participants reported 15.3% lower total workload and 18.8% higher self-reported performance when driving through the JLM. The analysis of results with respect to gender shows that male participants had lower speed when driving through the work zones. Overall, female participants exerted more force on the brake pedal and had 4.7% less travel time. Female participants tended to change lanes sooner when they encountered a work zone and they experienced 39.5% higher total workload. Participants with type A personality, who are hard driving, ambitious and time conscious, as opposed to type B, remained in the closed lane longer and drove through the work zones with3.3% lower speed.

The results show that people with aggressive tendencies exerted less braking force, finished the experiment faster and experienced less workload. Participants with previous traffic offenses experienced 8% higher total workload, exerted 78% more braking force and had 3% shorter travel time than those without any traffic offenses. Participants with less than a year of driving experience had significantly more frustration than experienced drivers. Furthermore, those with one to three years of driving exerted 56% lower braking force compared to those with more than three years of experience. Lower self-reported workload measures for the JLM suggest that the JLM is more conducive to driving. In conclusion, the evidence suggests that the joint merge outperforms the conventional merge.

Table of Contents

List of Figures

List of Tables

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation, University Transportation Centers Program (UTC) in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

Acknowledgements

This study was supported by a grant from the U.S. Department of Transportation, University Transportation Centers Program (UTC). The authors acknowledge the support of the Southwest Region University Transportation Center and its consortium member, the Gulf Coast Research Center for Evacuation and Transportation Resiliency (CETR).

1 INTRODUCTION

1.1 INTRODUCTION

Transportation in the United States, like any other developed country, is facilitated by road, air, rail and marine networks. However, the importance of road networks as the major mode of commercial and personal transportation is paramount in the United States. As the number of road users increases, so does the necessity for maintenance and rehabilitation of existing highways. Traditional asphalt has an average lifespan of about 16 years[1], which necessitates periodic maintenance and rehabilitation. Since it is not always feasible to stop traffic flow in order to perform maintenance on a road, the common practice is to only close the lane where rehabilitation is going on and guide the moving vehicles to the open lane.

Work zones critically affect and disrupt the regular traffic flows [2]. The first challenge faced by transportation officials and contractors is determining how to reduce the negative impacts of work zones on driver mobility. Motorists throughout the United States have cited work zones as the major cause of traveler dissatisfaction [3]. A 1995 survey conducted by the Federal Highway Administration (FHWA) revealed that only 29%of respondents were satisfied with traffic flow through work zones. Daily road user costs on many urban freeway reconstruction projects total over $50,000 per day [4]. Furthermore, with the increase in the number of cars and highway networks, there is a growing concern regarding road safety among many road users. Roadway work zones are hazardous both for motorists who drive through complex arrays of signs, barrels, and lane changes and for workers who build, repair, and maintain streets, bridges, and highways. Thus, the second challenge at freeway work zones is determining how to guide the motorists efficiently and safely through the work zone areas [5]

Extensive literature on the current conventional merging layout introduced by U.S. Department of Transportation [6], suggests that conventional merge suffers from long queues during peak hours and a large number of reported rear end and side swipe crashes. Several researchers have studied the efficiency of different merge configurations in terms of metrics such as throughput, number of forced merges [7], vehicles operating speed [8], deceleration [5], travel time [9], and other traffic flow characteristics. However, despite all the efforts to modify merge configurations and improve work zone safety, the high rate of crashes and fatalities in work zone areas are still unacceptable. A study on the crash forensics analysis of work zone areas in Kansas suggest that 92% of work zone crashes occurred due to drivers' misbehavior such as reckless or aggressive driving [10]. This indicates that the current safety measures and applied policies are deficient in reducing risky driving behavior [11, 12]. From a human factors perspective, driving requires performing physical and cognitive tasks under time pressure and this makes driving through work zones physically, mentally, and temporally demanding. In order to ensure safety, health, comfort, and long-term efficiency of drivers in work zones, designers should regulate task demands so that drivers can perform merging maneuvers efficiently without being mentally overloaded. Hence, understanding how drivers with different personalities respond to changes in the driving environment and what road characteristics trigger risky driving behavior is a crucial step in improving work zone safety. In order to provide safe and smooth travel for drivers in work zones, this research investigates the interactions between driver characteristics and behavior with traffic conditions. The objectives of this study are: 1) to determine the effects of work zone configuration, traffic flow levels and the distance between traffic signs on driver behavior,2)to determine the effect of individual differences on driving behavior, and 3) to demonstrate the use of human factors analysis techniques applied to the understanding of driver behavior and performance in high way work zones.

1.2 Background

Americans lose 3.7 billion hours and 2.3 billion gallons of fuel every year sitting in traffic jams [13]. Accordingly, nearly 24% of non-recurring freeway delays, or about 482 million hours, is attributed to work zones [14]. The annual fuel loss due to work zone congestion can be estimated as $714 billion [15].

Driving is a complex task characterized by multiple factors that require a driver to process information continuously. Driving through construction work zones is particularly complex yet a common occurrence for most drivers. A typical driver passes a construction zone approximately every 100 miles [16]. According to the National Center for Statistics and Analysis [17], there were 87,606 crashes in work zones in 2010 which is 1.6% of the total number of roadway crashes (5,419,345). Of the total work zone crashes, 0.6% were fatal crashes, 30% were injury crashes, and 69% were property damage crashes. Table 1.1categorizes types of recorded crashes in 2010 based on the roadwork shift time and the part of the work zone in which the crash happened. According to these data, rear-end crashes are the most typical type of collision in work zones.

Table 1.1 Percentage of crashes by collision type [18]

	Night Work			Day Work		
Type of Collision	Active Work With Lane Closures	Active Work Without Lane Closures	No Active Work or Lane Closures	Active Work With Lane Closures	Active Work Without Lane Closures	No Active Work or Lane Closures
Rear-End	38.4%	33.6%	26%	46.9%	54.4%	48.7%
Sideswipe	15.8%	21%	15%	13.6%	14.8%	14.8%
Fixed-Object Collisions	22.8%	21%	31.9%	2.3%	1.3%	15.9%
Other Collision Types	23.1%	24.4%	25.2%	19.2%	2.6%	14.1%

Records show that in 2010, there were 514 fatal motor vehicle crashes in work zones, resulting in 576 fatalities. These 576 fatalities equate to one work zone fatality every 15 hours[19]. However, the number of fatalities in work zones appears to be declining. Figure 1.1 shows the number of fatalities in work zones from 2005 to 2010.

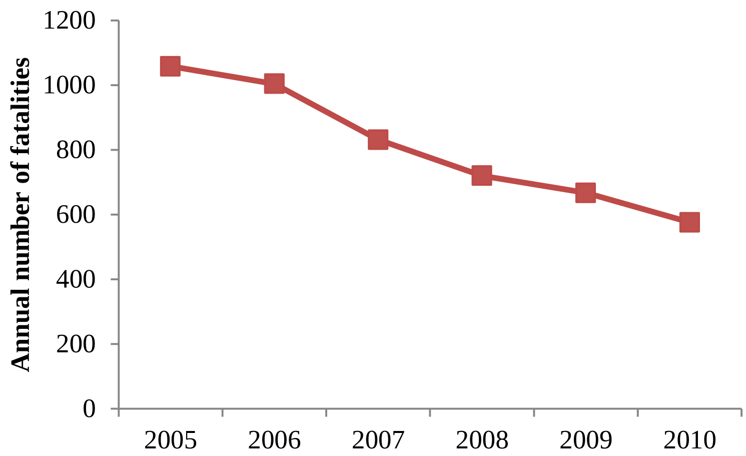

Figure 1.1Annual number of fatalities in work zone related crashes in the U.S. between 2005-2010 [17]

Figure 1.2shows the percentage of fatalities for different road types. Interstate highways had the highest percentage of fatalities. The overall trend in highway fatalities shows a 23% decline from 2002 to 2010, while work zone fatalities declined 51% during the same eight year period [17].However, the number of accidents and injuries that occur in work zones is still high and therefore, there is still a need to enhance safety of interstate highway work zones.

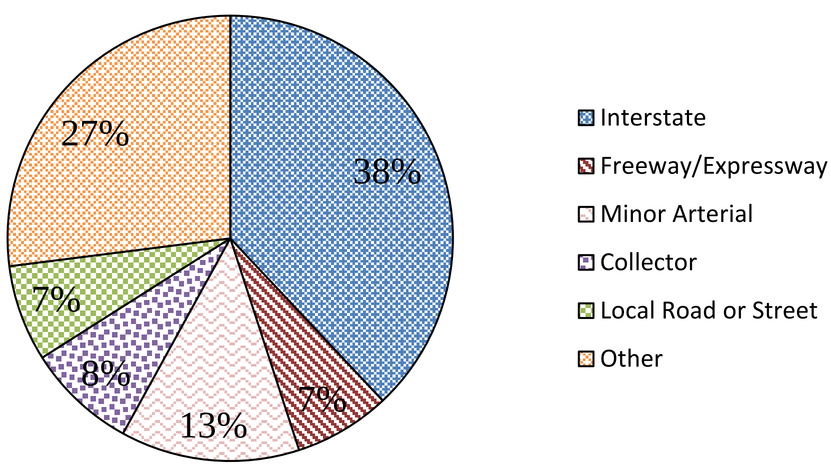

Figure 1.2 Percent fatalities in work-zone accidents for different roadway classes in the U.S [17]

1.3 Purpose and scope

In order to provide safe travel conditions for drivers in work zones, the department of transportation in each state in the U.S. stipulates using different merging strategies to guide drivers in the closed lane safely to the open lanes. Researchers have studied the efficiency of merging strategies in terms of safety, throughput, and travel time and traffic mobility characteristics[5, 20-25]. This research investigates the efficiency of an alternative merging strategy known as joint merge [24] in terms of its effects on drivers' behavior and traffic flow characteristics by using a full-size driving simulator combined with human factors analysis techniques. Ultimately, this research compares the performance of joint merge with the conventional merge configuration proposed by Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) [6]. Understanding driver behavior is critical to improving the safety of roadways, particularly in construction zones, high-traffic areas, and evacuation scenarios. Specifically, this research will address the following three objectives:

1. To determine the effects of merge configuration, traffic patterns and traffic flow levels on driver behavior
2. To determine the effects of individual differences on driving behavior
3. To demonstrate the use of human factors analysis techniques applied to the understanding of driver behavior and performance in work zones

2 LITERATURE REVIEW

2.1 INTRODUCTION

A highway work zone is a part of the road where construction or road maintenance takes place. Work zones impede traffic flow and create congestion. In order to keep the continuity of movement for motor vehicles, temporary traffic control plans (TTC) should be used. Some of these plans are introduced in the Manual of Uniform Traffic Control Devices (MUTCD) which is a national standard in the U.S. for traffic control devices used on all public streets and highways[6]. According to MUTCD, a common TTC includes flaggers, traffic signs, arrow panels and portable changeable message signs, channelizing devices, pavement markings, lighting devices, and temporary traffic control signals [6].

Lanes in a typical work zone can be classified into two types: merge lanes and through lanes. A merge lane is the lane that is closed due to road work and a through lane is the one that is left open for vehicles to pass by. Vehicles in the merge lane are expected to complete their merge and go to the through lane before they enter the work zone area. However, studies show that the majority of drivers remain in the merge lane and perform their merging maneuvers in the work zone area which results in traffic congestion and in some cases accidents [26]. According to a field study of driver behavior near work zones[27]94.4% of drivers in the merge lane started to change lanes at about 500 feet before the road taper. In general, the merge lane should be long enough so that at least 85% of drivers can complete their merging maneuvers[28, 29].Makigami *et al.* [28] developed an analytical method to determine the necessary merging length and concluded that 700 m is an optimal length for transition section in three and four lane highways.

Inefficient planning for traffic operation control near work zones can lead to high traffic queues, additional fuel consumption, an increased number of forced merges and an increased chance of roadway accidents [30]. Research on improving the operational efficiency of work zones in recent years has led to the advent of new merge configurations. In addition to Conventional Lane Merge (CLM) which is recommended by the United States Department of Transportation,[6], there are other configurations such as early merge, late merge and zipping that are used in different parts of the U.S. However, despite all the efforts to modify merge configurations and improve work zone safety, the high rate of crashes and fatalities in work zone areas are still unacceptable and the need to examine new merge configurations and improve efficiency and safety of merging maneuvers still exists. New configurations can be designed by using special geometric configurations and advanced signage that lead to improvements in the merging experience of drivers at work zones [9].

This chapter provides an overview of several studies that evaluated the operational efficiency of the CLM strategy, along with some unconventional lane merge configurations such as static early merge, static late merge, dynamic early merge, dynamic late merge and zipping. Furthermore, the effects of other variables such as gender, age and drivers' characteristics on driving behavior in work zones are discussed.

2.2 MERGING STRATEGIES

2.2.1 Conventional Merge

The current lane closure design (CLM) specified in the MUTCD[6],is the most commonly used design in the U.S. and seeks to guide drivers from the closed lane to the open lane safely. Under the CLM configuration, when two lanes merge into one lane, vehicles in the open lane are given the right of way, while those in the closed lane are expected to move into the open lane before the two lanes merge (Figure 2.1). Vehicles in the open lane are given the opportunity to continue to move into the work zone area without stopping, but vehicles in the closed lane may have to slow down or stop if the merging gaps in the open lane are limited [31]. However, the safety of this merging configuration is only effective in low to moderate traffic densities [5].Some advantages of the CLM in the U.S. are its widespread usage and drivers' familiarity with the incorporated traffic signs. However, increased potential for rear end and side swipe crashes and longer queue lengths in high traffic density are the drawbacks of this merge [5].

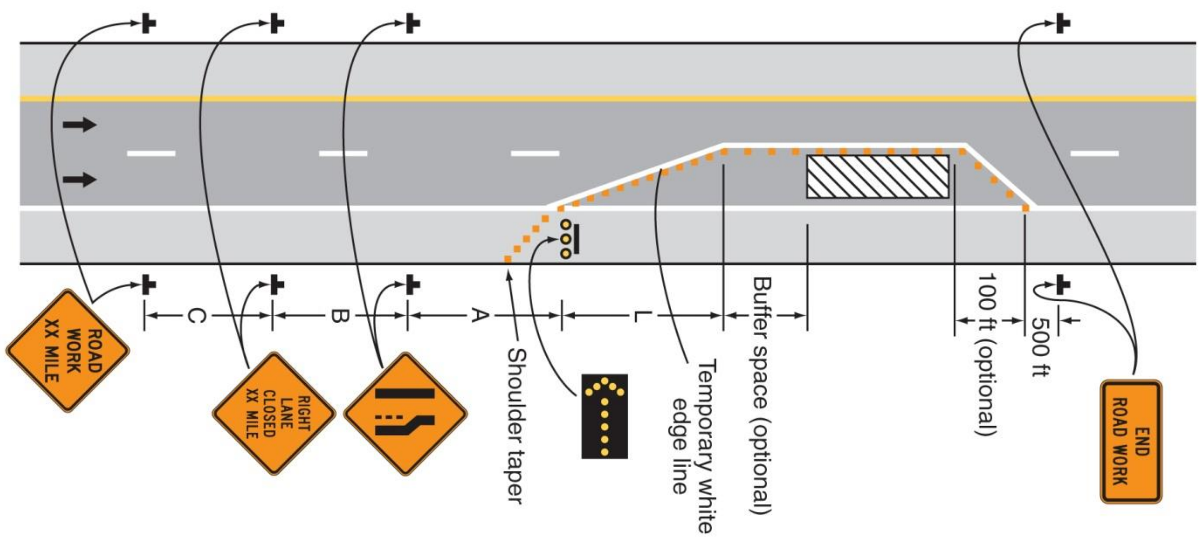

Figure 2.1 Conventional merge design layout [6]

2.2.2 Early Merge

Early merge aims at providing enough response time for drivers approaching a merge by means of placing warning signs in advance of the taper [25]. Early merge is divided into static early merge and dynamic early merge. In static early merge, drivers are informed about the upcoming lane closure by advance "LANE CLOSED" signs placed nearly 1.5 miles before the taper. Also, lane reduction signs are placed 1500 ft. before the taper, followed by flashing arrow panels at the beginning of the taper. This type of lane merge is suitable when demand is below capacity but fails as congestion develops due to speed variation between lanes as drivers in the closing lane tend to pass those in the open lane. Contrary to static early merge where sign distance intervals are fixed, the signs in dynamic early merge are responsive to real time traffic measurements (Figure 2.2). When stopped vehicles are detected by sonic detectors near the signs, a signal is transmitted to the nearest upstream sign. Signs in dynamic early merge are placed at either .25-.5 mile intervals upstream of the lane closure. When the signal is received by a sign, it alerts the drivers by showing a "DO NOT PASS" message. Another difference between early static and dynamic merge is the incorporation of beacon lights in dynamic merge. The lights are deactivated once a stopped queue is no longer detected.

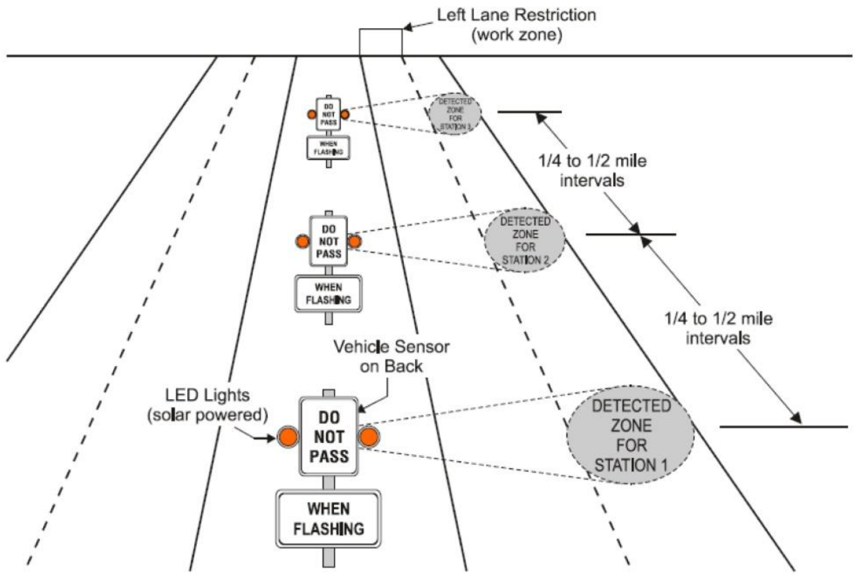

Figure 2.2 Dynamic early merge design layout [25]

Early merge strategies may be successful in reducing the number of forced merges in the transition area, however, travel times during high traffic density may increase [32]. Tarko *et al.* [33] found that using early dynamic merge strategies increased the size of queues and length of merging zones due to the reduction of speed in the open lane, especially during high traffic. McCoy and Pesti [25]found a smooth merging behavior in low traffic with the dynamic early merge, but abrupt decelerations and large queue lengths during high traffic led to a reduction in throughput. Early merge strategies potentially can reduce traffic volume. However, as with the CLM, its efficiency declines in high traffic density, and chances of accidents and aggressive driving increase.

2.2.3 Late Merge

The late merge strategy was proposed to reduce aggressive driving behavior between motorists in the closed and open lanes [25] (Figure 2.3). In this strategy vehicles are encouraged to stay in their lanes until they reach the merge section. As like the early merge strategy, late merge is also divided into static late merge and dynamic late merge. The concept behind the late merge is to encourage drivers to use both lanes until a specified merging point. Once vehicles reach the merging point, those in the closed lane merge with vehicles in the open lane in an alternating pattern. Typically, a "Use Both Lanes to Merge Point" sign is placed approximately 1.5 mile (2.4 km) in advance of the taper.

Several researchers studied the efficacy of late merge configuration in terms of traffic flow characteristics and safety in work zones. Beacher *et al.* [8]compared the CLM and static late merge configurations and found that except for positive response from drivers towards static late merge, no significant difference in throughput compared to the CLM was found. Similarly, Kang *et al.* [34] concluded that the behavior of the dynamic late merge strategy is analogous to the CLM in unsaturated traffic densities. According to McCoy and Pesti [25] forced merges in the late merge strategy was 75% lower than CLM at high densities. Forced merges occur when there is not enough space between vehicles in the closed lane and open lane and as a result, the vehicles in the closed lane attempt to merge with evasive maneuvers. The result also showed 30% fewer lane straddles at densities below 25 vehicles per mile. Finally, a study by Grillo *et al.* [35] found that the dynamic late merge configuration is more effective on highways with moderate to heavy congestion prior to construction work zones. As a result, benefits of the late merge lie in its application in high volume traffic. It reduces rear end crashes and creates shorter queues. However, compliance of drivers to this new strategy is low which creates hazards in low volume traffic [8].

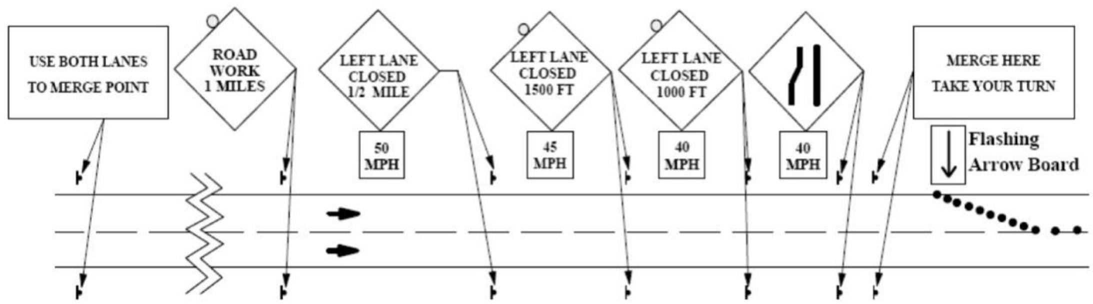

Figure 2.3 Late merge design layout [21]

2.2.4 Zipping

An alternate merging strategy called "zipping signs" is used in the Netherlands, Belgium and Germany (Figure 2.4). In this strategy, during congested periods, vehicles in the open lane permit adjacent vehicles to merge in an alternating pattern until the congested period ends. Dijker and Bovy [36] studied the performance of zipping strategy in the Netherlands, and found that compared to other configurations, zipping maneuvers do not affect throughputs in the zipping strategy. In the United States, the Connecticut Department of Transportation proposed a test sign similar to the zipping sign [37]. This sign was the result of two surveys that showed it was the statistically best understood sign among 6 proposed signs (Figure 2.5). This test sign was used in the field along with the W 4-2 sign and the results showed that the test sign had statistically increased the desirable number of merges from 56% to 66% and reduced the undesirable merges from 9% to 5%. One advantage of this merging strategy is that speed is better maintained as motorists travel through the merging area [38].

Figure 2.4 Zipper sign (Risten) in the Netherlands

(a) (b)

Figure 2.5 (a) MUTCD W4-2 (b) Experimental merge sign

2.2.5 Always Close Right Lane

This strategy, which is commonly used in Arkansas, advocates for closing the right lane at all times. Drivers who are familiar with the rules know ahead of time which lane is ending. Once the first merge is completed, drivers are channeled to the appropriate side of construction. Although the effects of this type of strategy are not well documented, one study showed that the crash rate in always close right lane configuration was 46% lower than the CLM[39]. This configuration creates less confusion on which lane is closed and may reduce the number of sideswipe crashes. It is widely recognized that when congestion develops and queues form at the approach to work zones, the risk of crashes increases, especially on major highways where speeds are high and drivers are accustomed to unencumbered travel. Additionally, the problem can be compounded by limited sight distance and roadway curvature. As a result, in high traffic density, increased back-of-queue crash at lane closures in always close right lane strategy presents a very serious safety condition.

2.2.6 Joint Merge

The crash analysis results of work zone areas show that the rate of crashes in advance warning areas where drivers usually perform their merging maneuvers is higher compared to other parts of the road[40]. Therefore, the Joint Lane Merge (JLM) configuration was proposed as an alternative to the CLM configuration [24, 38] with more emphasis on the configuration of the transition area. In the JLM configuration (Figure 2.6), motorists in both lanes have equal right of way, as opposed to CLM where only the open lane has the right of way. The JLM configuration is divided into five distinct zones as shown in Figure 2.6. The advance warning zone in the JLM is typically a mile long and compared to the CLM includes more traffic signs to inform drivers about the upcoming road conditions. At the end of the advance warning zone, two blinking arrow signs are placed on both sides of the road, suggesting that vehicles should merge by taking alternating turns over the transition area. The transition zone is divided into three sections. In the first section, both lanes are tapered from the full lane width (typically 12 ft) to nearly 6 ft to form a single lane of 12 ft. In the second section, vehicles merge to the center line, and in the third section vehicles are guided by the flashing arrow sign either to the right or left lane, depending on the open lane in the work zone area. The activity and termination areas in the JLM configuration are identical to those in the CLM configuration.

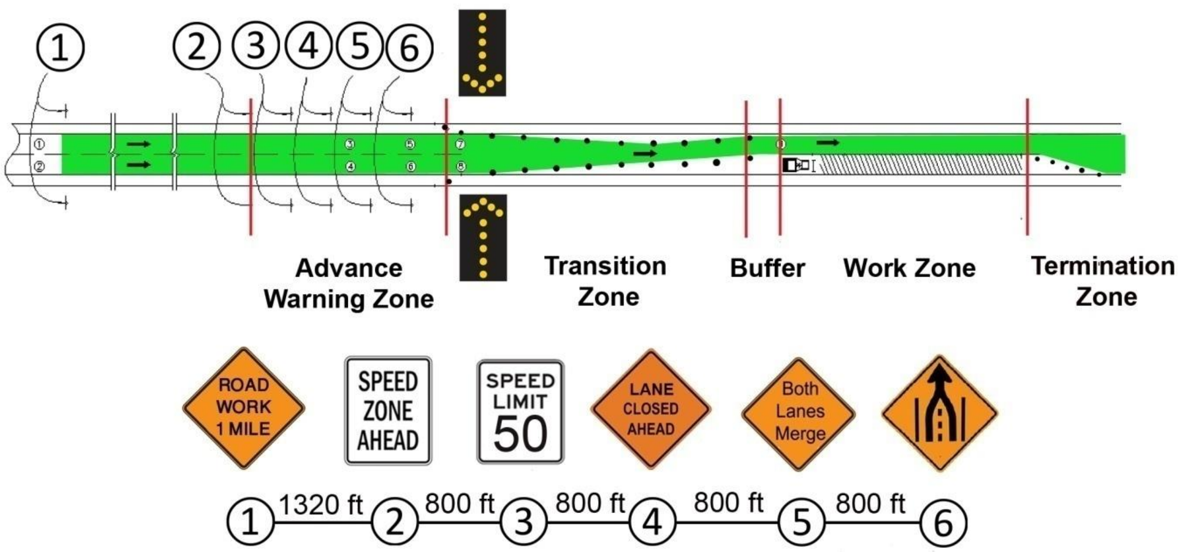

Figure 2.6 Joint lane merge configuration layout

Several studies evaluated the operational efficiency of joint merge. Idewu and Wolshon [24] conducted a field study to evaluate the effects of the JLM on traffic in a controlled work zone in Louisiana. The comparison of merging speed between the JLM and CLM showed no significant difference at volumes ranging from 600 to 1,200 vehicles per hour (vph). However, the experimental results did suggest that drivers going through the JLM were more cautious in their merging maneuvers. Ishak *et al.* [5] examined and compared the safety performance of the conventional lane merge configuration with joint merge in terms of uncomfortable decelerations and speed variance by using a microscopic simulation model (VISSIM). Results showed that in most simulation scenarios, for the advance warning zone, the CLM configuration exhibited lower frequency of uncomfortable decelerations as opposed to the JLM configuration. However, for low flow rate of 500 vph, no significant differences were detected. For the transition area, in most scenarios with low to moderate flow rates (500–1500 vph) the JLM configuration had less frequent rate of uncomfortable decelerations and therefore was considered safer than the CLM configuration. In another study, Rayaprolu *et al.* [9] compared performance measures in terms of total throughput and average delay time between CLM and JLM. Their results showed that at low levels of demand (500 and 1000 vph) both configurations had similar operational performance in terms of throughput and average delay time. At high levels of demand The JLM had significantly higher throughput and shorter delays than the CLM.

Open literature regarding lane merge configuration is replete with studies focusing on the operational aspects of merge configurations like operating speed, throughput, delays, etc. Despite efforts to modify merge configurations and improve work zone safety, the high rate of crashes and fatalities in work zone areas are still unacceptable which indicates that the current safety measures and applied policies are deficient in reducing risky driving behavior [11, 12].

Studies show that drivers' behavior contributes significantly to 90–95% of crashes [41] in which, risky and aggressive driving appears to be the dominant human factor [42]. Researchers have tried to explain the relationship between individual differences on risk taking behavior with accident involvement [43]. Drivers with risky driving behavior frequently speed and change lanes aggressively, fail to give way to other vehicles or pedestrians and ignore traffic control signs [44]. Many researchers found that risky behavior on roads is influenced by gender. In one study, Yagil [45] reported that male drivers, particularly younger individuals, are more likely to disobey traffic rules. Furthermore, the results showed that male drivers perceive traffic violations as less dangerous as do females. Chliaoutakis *et al.* [46] used previous driving violations and irritability as factors for predicting aggressive driving. The latter factor was more rampant among young drivers who easily lose their temper and express their anger by showing reckless driving. Chen [47] studied the relationships between personality factors, attitudes toward traffic safety and risky driving behaviors among young Taiwanese motorcyclists. His findings show that attitudes toward traffic safety are directly associated with risky driving behaviors and traffic safety. Moreover, personality traits are indirectly mediated by traffic safety attitudes and also are found to influence risky driving behaviors.

From a human factors perspective, driving requires performing physical and cognitive tasks under time pressure, and this makes driving through work zones physically, mentally, and temporally more demanding. High demand tasks result in so-called workload overload that may create stress for drivers and increase the risk of accidents [48]. In order to ensure safety, health, comfort, and long-term efficiency of drivers in work zones, designers should regulate task demands so that drivers can perform merging maneuvers efficiently without being mentally, physically and temporally overloaded. However, there is dearth of information on how drivers react to different work zone configurations. Understanding how drivers respond to changes in the driving environment and what road characteristics trigger risky driving behavior near work zones is a crucial step towards improving work zone safety. The existing literature clearly suggests that many factors determine the efficiency of a merge configuration. These factors are divided into two broad categories: geometric configurations factors and human behavioral factors. The aim of the present study is to determine the effects of merge configuration, traffic patterns and traffic flow levels on driver behavior and demonstrate the use of human factors analysis techniques applied to the understanding of driver behavior and performance in work zones.

This page is intentionally left blank.

3 METHODS

3.1 STUDY DESIGN

The effects of merge configuration, traffic patterns and traffic flow levels on driver behavior near work zoneswas measured by using a full passenger driving simulator. The experiment consisted of a 2x2x3x4 within-subjects design manipulating merge type, traffic density, sign distance, and zone. This research was approved by the LSU Institutional Review Board (IRB) and all participants signed a consent form before starting the experiment. The effects of scenario order were minimized by assigning scenario order with a fully counterbalanced Latin Square design.

3.2 PARTICIPANTS

Participants in this study were recruited through convenience sampling from Louisiana State University. Seven female and 21 male students participated in the study. The criterion for inclusion was having a valid driving license. The age range of participants was 20-29 years with the median of 4.5 years of driving experience and at least 1,000 mile per year. The results of self-reported questionnaire regarding driving experience showed that out of 30 participants, two of them were involved in an accident previously and 10 of them had violated road regulations resulting in ticket in the past 12 months.

3.3 TOOLS

An on road high-fidelity driving simulator (Realtime Technologies Inc., Baton Rouge, LA) was used in this study to simulate driving experience through a construction zone (Figure 3.1). The simulator was a full size passenger car on a one degree-of-freedom motion base, providing realistic motion cues to the driver, and was surrounded by four screens showing front, rear, left and right views. The side-mirrors consisted of two LCDs which showed the rear view of the road. There were three cameras inside and one camera outside the car to record drivers' eye movement, foot position on accelerator and gas pedals, steering wheel and ambient traffic flow.

Figure 3.1 View of driving simulator

3.4 EXPERIMENTAL MODEL

Twelve work-zone scenarios were designed based on an interstate highway driving environment and refined according to the needs of this experiment (merge configurations, distance between traffic signs and traffic density).

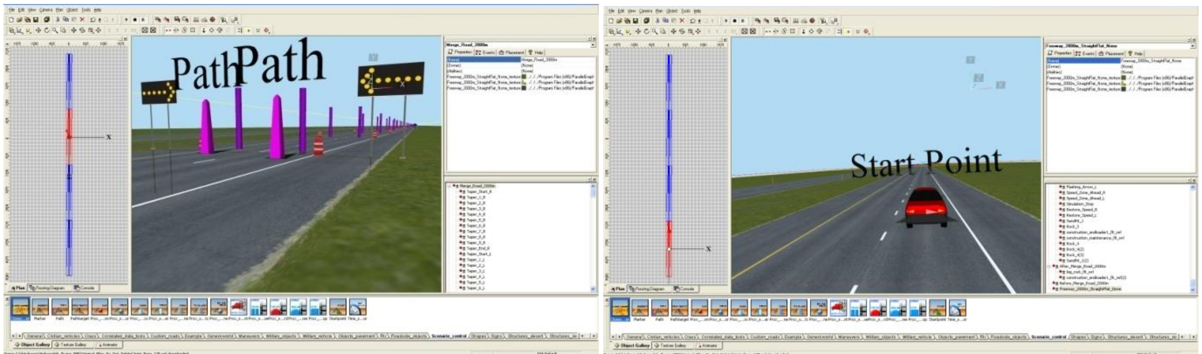

Figure 3.2 Developing construction zone layout for driving simulator

The route comprised of 3.7 mile (6km) long four lane divided highway with a construction zone located on the right lane. There were no traffic lights, yield signs or stop signs. All scenarios had a speed limit of 70 mph (112km/h). Work zones were designed with a speed limit of 50 mph (80 km/h).The signs presented speed and distance in English units. A speed limit sign of 70 mph was set at the start of the first condition. A big stop sign was placed at a point where the experimenters wanted to end the simulation. Participants were asked to stop before this sign before the simulation ended. The traffic density can be manipulated by the driving simulator. The maximum number of cars that the simulator can generate around the simulation car is 50. Thus, to simulate high traffic density we set the traffic criteria to 50 vehicles and for low traffic density we used 25 vehicles.

The CLM and JLM layouts were divided into five different zones as shown in Figure 3.3-4. These zones are (1) advance warning zone, (2) transition zone, (3) buffer, (4) work zone and (5) termination zone. The advance warning zone is typically a mile long and is primarily used to inform the motorists of what to expect ahead as they approach the work zone area. When redirection of the driver's normal path is required, traffic must be channelized from the normal path to a new path. This redirection is done in the transition area. The buffer space is an optional feature in the activity area that separates traffic flow from the work activity or a potentially hazardous area and provides recovery space for an errant vehicle. The work zone is an area of roadway where the work takes place. It is composed of the work space and the traffic space, and may contain one or more buffer spaces. The termination area is used to return traffic to the normal traffic path. The termination area extends from the downstream end of the work area to the END ROAD WORK signs, if posted.

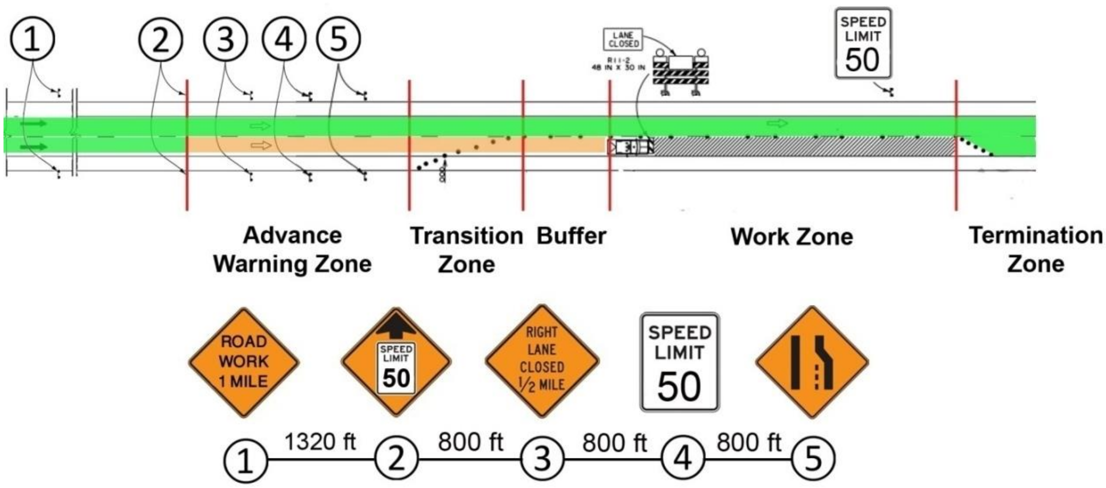

Figure 3.3 Conventional merge layout with right lane closure

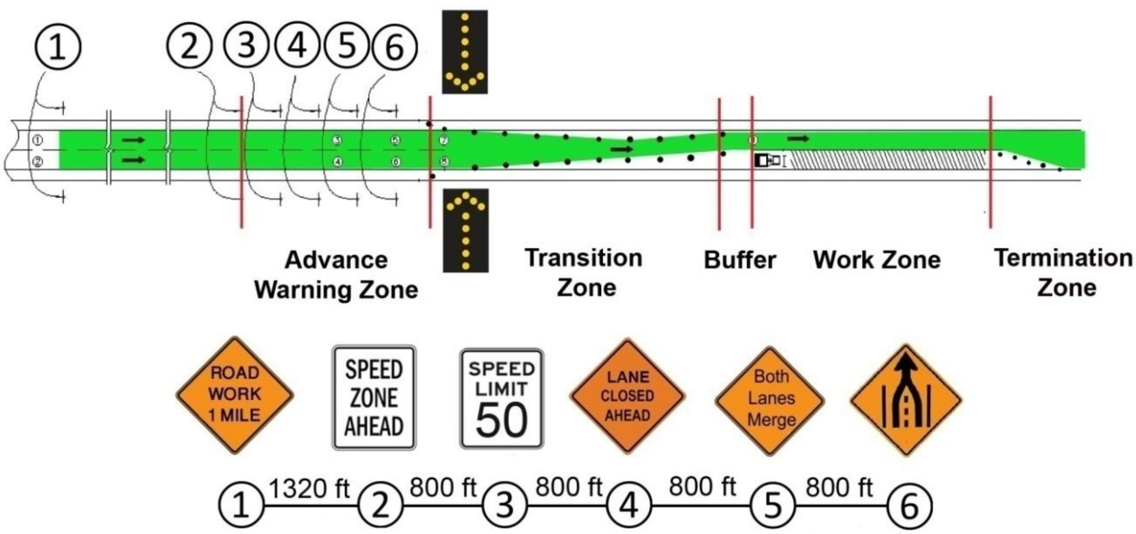

Figure 3.4 Joint lane merge configuration

3.5 INDEPENDENT AND DEPENDENT VARIABLES

The independent variables used in this study were:

- Merge configuration (CLM or JLM)
- Traffic density (high or low)
- Three levels of sign distance in the advance warning zone: the standard distances shown in Figure 3.3 and Figure 3.4 were multiplied by 1.25 and 0.75 to increase and decrease the distances between the signs by 25%, respectively.
- Zones (advance warning zone, transition zone, buffer and work zone) as shown in Figure 3.3and Figure 3.4.

The dependent variables used in this study were:

- Travel time (s)
- Average speed (mph)

- Percent maximum braking force (%)
- Location of changing lane (m)
- Drivers’ workload (%)

3.6 Materials

All questionnaires used in this study were paper and pencil tests. Work load was measured by NASA TLX questionnaire [49]. Information regarding previous offense and years of driving experience was collected by a demographic information questionnaire. Driving Anger Expression Inventory (DAX) [50], and Driver Behavior Questionnaire (DBQ) [42], were used to measure an individual’s inclination to get angry while driving and driving behavior and violations, respectively. Type A behavior was measured using the Bortner questionnaire [51]

3.6.1 Workload

NASA-TLX was used to measure self-reported workload variables. This tool defines individual workload variables that are task specific. It consists of six scales; Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration [52] as described in Table 3.1. Completing NASA TLX comprises of two parts. In the first part, participants are given a scenario task and after completing the task, they are given a list which consists of 15 pair-wise comparisons of the six scales. Participants should choose the scale which, in their opinion, contributed more to the overall workload. Adding up the number of times each scale is chosen provides a ‘weighting’ for that workload scale and is used to determine its contribution to total workload. In the second part, after each experiment, a rating sheet is given to participants and they are asked to rate the six scales. Each scale is presented as a 12cm line anchored by bipolar descriptors (e.g. low, high). Participants give their ratings by marking on an appropriate location on the line. The distance from the left end of the 12 cm line to the marking represents the rating for that scale. In this study, all ratings were standardized and converted to percent by using the following formula:

$$L_i = \frac{r_i}{12} \times 100 \qquad (1)$$

Where L_i is the percent load and r_i is the rating for the i^{th} scale. Total workload is calculated by using the following equation:

$$TotalWorkload = \frac{1}{15} \sum_{i=1}^{6} L_i \, w_i \qquad (2)$$

Where w_i is the weighting for the i^{th} scale derived from the pair-wise comparisons.

Table 3.1 . NASA-TLX rating scale and definitions

Workload Component	Endpoints	Definitions
Mental demand (MD)	Low to high	The mental and perceptual activity required by a task
Physical Demand (PD)	Low to high	The physical activity associated with a task
Temporal Demand (TD)	Low to high	The time pressure associated with the rate or pace required to complete the task
Performance	Excellent to poor	The degree of success or satisfaction felt upon the performance or completion of a given task
Effort	Low to high	The mental and physical work required to perform the task at a certain level
Frustration	Low to high	Refers to the continuum of stress and/or contentment associated with task completion

3.6.2 Driving anger expression inventory (DAX)

The DAX is a scale consisting of 49 items that asks individuals to rank how often they express anger in the described manner, using a four point Likert scale ranging from 1 = almost never to 4 = almost always[50]. These 49 items are grouped in four different subscales: Verbal Aggressive Expression (e.g., swearing or yelling at another driver), Physical Aggressive Expression (e.g., giving another driver the finger or trying to have a physical fight with another driver), Use of the Vehicle to Express Anger (e.g., speeding up to frustrate another driver or flashing lights at another driver), and Adaptive/Constructive Expression (e.g., relaxing or thinking about things to distract oneself from frustration).

3.6.3 Driving behavior questionnaire (DBQ)

The Driving Behavior Questionnaire was used to measure four driving behavior factors. These factors are aggressive violations, ordinary violations errors, and lapses. Aggressive Violations include emotional/interpersonal component (e.g. sound the horn to indicate annoyance) and "Ordinary" violations are those that are not aggressive but still intentional [53]. Errors are actions that create safety risks and Lapses are unintentional failure to pay attention which does not create serious risks [42]. DBQ consists of 27 questions. Participants are asked to indicate how often they commit each of the violations and errors mentioned in the question when driving. Responses are recorded on a five-point Likert-scale from "Never" to "Nearly all the time" and the score for each factor is the sum of scores related to that factor.

3.6.4 Bortner type A

The type A behavior pattern is characterized by excessive sense of time urgency, extremes of ambition, competitiveness, aggressiveness, punctuality and impatience [54]. This test consists of 14 rating scales. Each scale is composed of two adjectives separated by a 40 mm line. One of the adjectives for each scale represents a type A characteristics. Participants are required to specify where they belong along the line between two adjectives. The rating scores for each scale is obtained by measuring the distance from the beginning of the non-A adjective [51]. In this study, all ratings were standardized and converted to percent by using the following formula:

$$B_s = \sum_{i=1}^{14} \frac{s_i}{40} \tag{3}$$

Where B_s is the final cumulative score for Bortner test and s_i is participants' ratings for each scale. Participants with the final cumulative score of more than 7 were categorized as type A personalities and those who scored less than 7 were categorized as type B.

3.6.5 Motion sickness questionnaire

One of the risks of any experiment that includes a driving simulator is motion sickness. In order to make sure that all participants were healthy and did not have any sickness symptoms, a motion sickness questionnaire [55] was given prior to the driving part of the experiment. To track any accumulative symptoms throughout the experiment, the motion sickness assessment form was given to participants after every two scenarios.

3.7 PROCEDURE

Before commencing the scenarios, participants were briefed on the purpose and risks of the study and instructed how to complete the scenarios. After briefing a set of questionnaires was given to each participant:

1. Informed consent form (appendix 1)
2. Demographic information form (appendix 2)
3. The Manchester Driver Behavior Questionnaire (appendix 3)
4. Driving Anger Expression Inventory form (appendix 4)
5. Bortner Personality Type Test (appendix 5)
6. NASA TLX pair-wise comparisons (appendix 6)
7. Motion Sickness Assessment form (appendix 7)

Participants were provided with an explanation and examples of the NASA TLX response sheet, and the six subcomponents of workload were explained to them. On average, filling all the forms and answering the questionnaires took about 30 minutes. After that, participants were allowed to familiarize themselves with the simulator by driving on a test road. The test road was a two mile interstate highway with a work zone on the left lane. After completing the test, participants were asked to rank the importance of each component of NASA TLX over all others, by a process of pair-wise comparison. Adding up the number of times each component was ranked as more important over others provided a weighting for each workload component to determine the component's contribution to total workload.

During the experiment the researcher sat outside the simulator at a desktop station and controlled driving scenarios. Each participant drove the 12 different scenarios in a randomized order. Participants were requested to drive in their usual manner (within the bounds of the law), and to be at ease with the presence of the researcher, who was not there to judge performance, but to record results. The length of each drive was approximately two minutes. A 10 minute break was offered to all participants after the completion of the sixth scenario.

During the experiment the radio was off but the noise from ambient traffic was played through several speakers around the simulator. At the completion of each scenario, there was a 2 min break, during which the participant completed the NASA TLX rating sheet and motion sickness questionnaire. At the conclusion of all 12 scenarios, participants were thanked for their assistance. Figure 3.5shows the outline of steps discussed above.

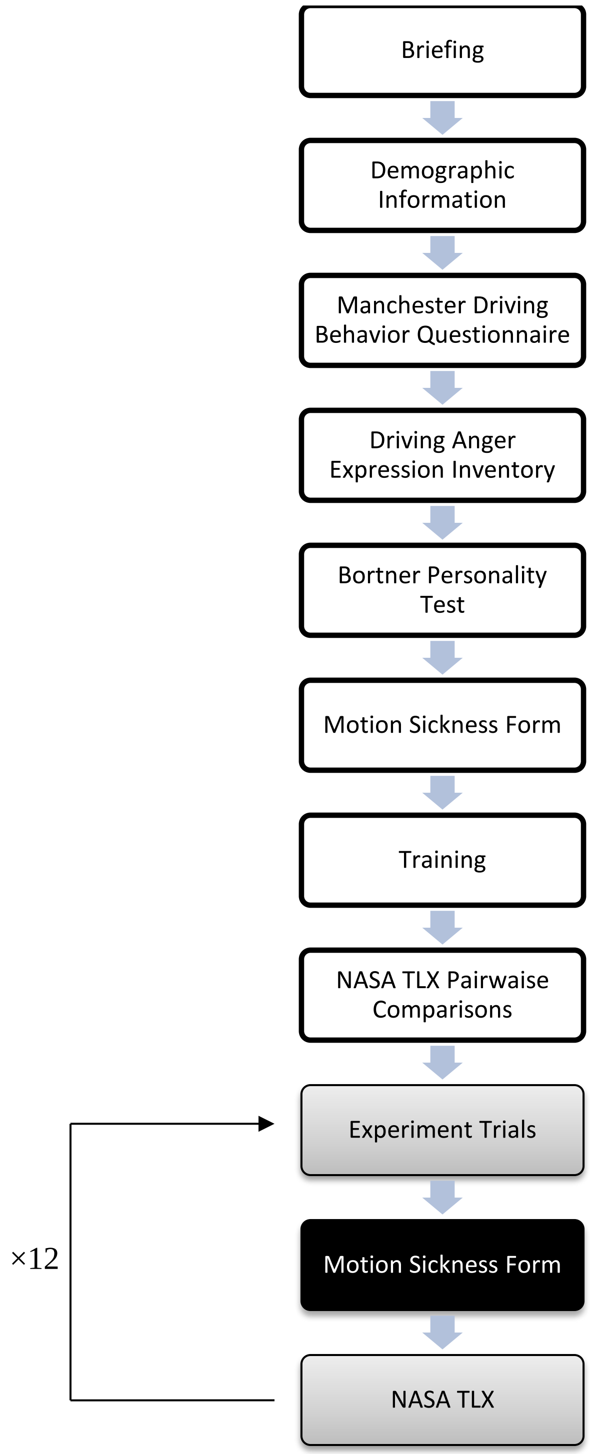

Figure 3.5 Experiment process outline; the white boxes represent the steps that are done once; the grey boxes represent the steps that are repeated for each experiment; the black box represent the step that is repeated after every two scenarios.

3.8 DATA ANALYSIS

All statistical analyses were done by using SPSS statistical package version 21[56].Tests of normality and homogeneity of variance were performed prior to conducting any inferential statistics. Results showed that speed and location of changing lanes were normal. However, normality tests for percent maximum braking force, travel time and NASA TLX scales showed that the Shapiro-Wilk statistic were significant (p <0.05) and therefore the distributions were not normal. Levene's Test of Equality of Variances showed that all the dependent variables including driving variables and workload scales had equal variances except for frustration $F(5,354)=3.548$, $p = 0.004$. For all the measures that did not achieve a satisfactory level of normality, the Johnson transformation SB method was applied using Minitab 16 [57]. Detailed explanation about Johnson transformation is given in Yeo and Johnson [58].

Descriptive statistics (mean and standard deviation) were calculated for all dependent variables. In the first step two Multivariate Analysis of Variance (MANOVA I and MANOVA II) were used to find the main factors. MANOVA I was used to evaluate how merge type, traffic density, sign distance, and zones affect physical driving variables such as travel time, Speed, percent maximum braking force, and location of changing lanes whereas MANOVA II was used to determine the effects of independent variables on NASA TLX subcomponents. The reason that two MANOVA models were used is due to the fact that one workload measurement was taken for each scenario and zone differentiation did not affect the data collection. However, for physical driving variables we were interested in collecting data for each zone and thus the dataset for physical driving variables was four times larger than that of for workload measurements. Statistically significant differences were accepted at p <0.05. Similarly two separate Multivariate Analysis of Covariates (MANCOVA I and MANCOVA II) was conducted to assess the effects of demographic variables and driving behavior characteristics on physical driving variables and driving workload. For each MANCOVA model gender, years of driving experience, previous traffic offense experience, aggressiveness and personality type were entered as covariates. The relationship between workload measurements and physical driving behavior was assessed by using Pearson’s Product Moment Correlations, with a threshold of significance of p <0.05.

In the final step, stepwise multiple regressions were conducted to exclude redundant variables and preserve those significant variables that contributed the most to the variance within each dependent variable. Therefore, several models were created, taking gender, years of driving experience, previous traffic offense, personality type, DBQ measures (aggressive violations, ordinary violations, lapses and errors) and DAX measures (verbal aggressiveness, physical aggressiveness, vehicular aggressiveness and adaptive behavior) as independent variables and NASA TLX self-reported measures of workload variables (mental demand, physical demand, temporal demand, performance, effort, frustration and total workload), speed, percent maximum braking force, travel time and merge location as dependent variables. The critical values for model entry and removal were $p = .05$ and $p = 0.1$, respectively.

4 RESULTS

The MANOVA I results show significant main effects for merge configuratin, Wilks' Lambda=0.794, $F(3,1390)= 120.531$, $p <0.001$, traffic density, Wilks' Lambda=0. 940, $F(3,1390)= 29.528$, $p <0.001$, distance between traffic signs, Wilks' Lambda=0.716, $F(3, 2780)= 84.216$, $p <0.001$ and zones, Wilks' Lambda=0.637, F(3, |3383)= 76.574, $p <0.001$. The results of MANOVA II show that self-reported measures of workload variables were influenced by merge configuration, Wilks' Lambda=0.949, $F(7,342)= 2.631$, $p <0.05$ and traffic density, Wilks' Lambda=0.959, $F(7,342) =2.100$, $p <0.05$. However, changing the distance between traffic signs was not a main factor for self-reported measures of workload, Wilks' Lambda=0.987, $F(7,684)= 0.324$, $p > 0.05$.

4.1 Effect of Merge Configuration

A series of univariate analysis of variance were conducted to compare the mean travel time, mean speed, percent maximum braking force and location of changing lane with respect to two merge configurations. Table 4.1 shows that there was a significant difference in mean travel time between two merge configurations with the CLM being 15.8 % lower, $F(1, 1392) = 337.535$, $p < 0.001$. No significant differences in the mean speed between the CLM and JLM were found, $F(1, 1392) = 3.729$, $p > 0.05$. However, the mean speed was slightly lower in the JLM. The univariate analysis of variance results show that merge configuration influences braking force and percent maximum braking forces in the JLM and CLM are statistically different from each other, $F(1, 1392) = 10.832$, $p < 0.05$.

Table 4.1Merge effect on discriptive statistics and the level of significance for physical and self-reported measures of workload variables

Measures	CLM		JLM		Difference (p value)
	Mean	SD	Mean	SD	
Travel time (s)	91.555	12.650	108.832	26.375	<0.001**
Speed (mph)	52.026	8.952	51.268	5.873	0.054
Percent maximum braking force (%)	4.297	10.599	2.833	8.598	0.004**
Location of changing lane (ft)	-1093.951	1386.052	-552.780	2931.465	0.026*
Mental demand (%)	33.811	28.212	28.265	26.045	0.053
Physical demand (%)	14.720	15.054	15.301	15.540	0.717
Temporal demand (%)	32.419	27.316	24.816	23.763	0.005**
Performance (%)	20.707	19.648	16.803	17.913	0.052
Effort (%)	27.934	26.209	24.095	26.560	0.170
Frustration (%)	16.386	18.164	11.795	13.746	0.007**
Total Workload (%)	28.099	20.959	23.800	20.066	0.048*

* $p <0.05$

** $p < 0.01$

Overall, JLM required 18% less braking force compared to the CLM. The comparison of two merge configurations with respect to the location of changing lanes shows that merge configuration, significantly affects the location of merge, $F(1, 358) = 5.014$, $p < 0.05$. The results show that drivers in the CLM configuration, on average, changed their lane 1094 ft before the start of taper in the transition zone. On the contrary, in the JLM, drivers started to change lanes on average at 553 ft before the taper which means drivers going through the JLM remain longer in the closed lane.

Figure 4.1 shows that temporal demand, $F(1,348) = 7.921$, $p < 0.05$, frustration, $F(1,348) = 7.342$, $p < 0.05$ and total workload, $F(1,348) = 3.955$, $p < 0.05$, were significantly different in the CLM and JLM. Participants' self-reported workloads indicate that JLM required less mental demand, temporal demand, performance, effort and frustration. Accordingly, total demand in JLM was 15% lower than that of in the CLM. Among all six scales of NASA TLX, mental demand with 33% for conventional and 28% for joint merge was the dominant workload. The largest difference between CLM and JLM was observed in frustration with 28% lower workload for the JLM. The second and third largest differences belonged to temporal and performance with 23% and 18% lower workload for the JLM, respectively. Except for physical demand in which JLM had only 3% higher workload, the remaining measurements for NASA TLX scales were all lower in JLM. This suggests that driving through Joint Lane Merge required less effort and participants were more satisfied with their performance.

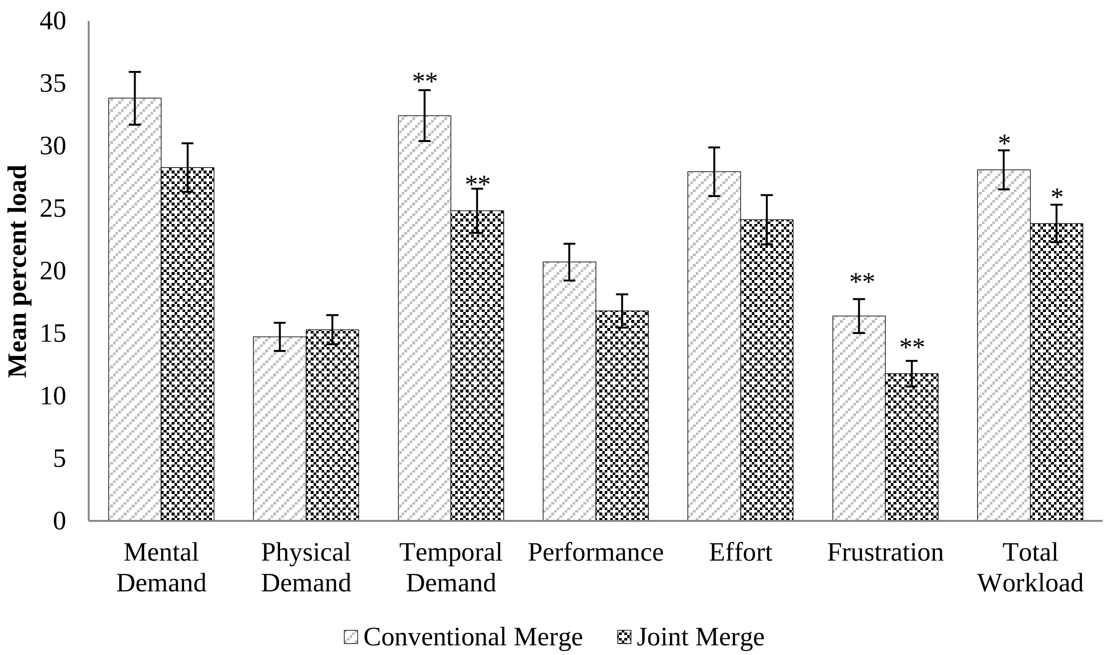

Figure 4.1 Effects of merge configurations on self-reported workload

4.2 Effect of Traffic Density

The results of univariate analysis of variance show no significant difference in mean travel time between the high and low traffic density, $F(1,1392) = 0.025$, $p > 0.05$ (Table 4.2). However, there were significant differences in speed of vehicles, $F(1,1392) = 61.210$, $p < 0.001$ and percent maximum braking force, $F(1,1392) = 9.158$, $p < .05$.The average of operating speed in the low traffic density was 5% higher and as opposed to high traffic density, participants in the low traffic density exerted 32% lower force on the braking pedal.

Table 4.2 Traffic effect on descriptive statistics and the level of significance for physical and self-reported measures of workload variables

Measures	High Traffic Density		Low Traffic Density		Difference (p value)
	Mean	SD	Mean	SD	
Travel time (s)	100.268	14.901	100.119	100.268	0.873
Speed (mph)	50.311	5.508	52.983	50.311	<0.001**
Percent maximum braking force (%)	4.238	10.374	2.892	4.238	0.008**
Location of changing lane (ft)	-972.407	2475.045	-674.323	-972.407	0.220
Mental demand (%)	35.295	27.802	26.780	35.295	0.003**
Physical demand (%)	17.460	16.478	12.561	17.460	0.002**
Temporal demand (%)	31.844	24.992	25.391	31.844	0.017*
Performance (%)	20.025	18.674	17.485	20.025	0.205
Effort (%)	28.818	26.285	23.212	28.818	0.046*
Frustration (%)	16.263	16.294	11.919	16.263	0.011*
Total Workload (%)	28.854	20.806	23.045	28.854	0.008**

* $p < 0.05$

** $p < 0.01$

The results show that traffic density was not a main effect for the location of changing lanes, F(1,358) = 1.506, $p > 0.05$, and therefore we failed to reject the null hypothesis that the distances of merging from the beginning of transition zone under different levels of traffic density are equal. However, in low traffic density participants were inclined to remain in the closed lane longer and on average changed their lanes 674 feet prior to the transition zone.

Traffic density has a significant influence on mental demand, F(1,348) = 8.920, $p < 0.05$, physical demand, F(1,348) = 9.393, $p < 0.05$, temporal demand, F(1,348) = 5.705, $p < 0.05$, effort, F(1,348) = 4.022, $p < 0.05$, frustration, F(1,348) = 6.572, $p < 0.05$ and total workload, F(1,348) = 7.225, $p < 0.05$. The results show that lower traffic density results in lower workload for all self-reported measures of workload variables. On average, participants driving in the scenarios with low traffic densities experienced 20% lower total workload and their self-reported performance 12% better in the low traffic density. The findings show that mental demand followed by temporal demand and effort were the three major contributors to the total workload. The largest differences between loads in high and low traffic densities were observed in physical demand, frustration and mental demand with 28%, 26% and 24% reduction in workload, respectively in low traffic density (Figure 4.2).

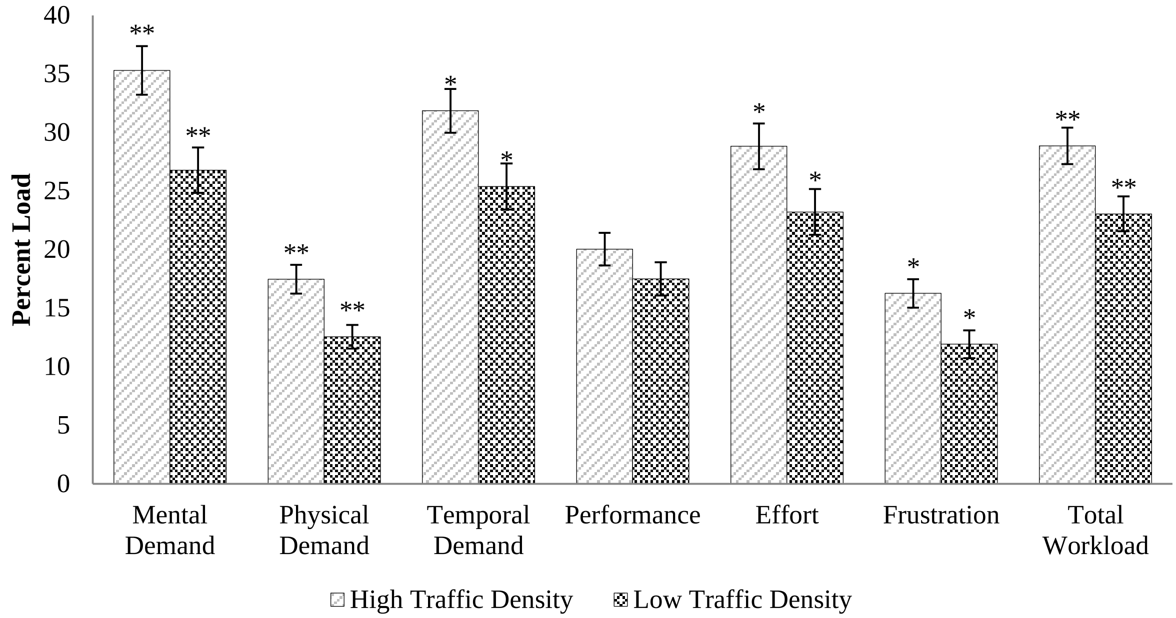

Figure 4.2 Effects of Traffic density on self-reported workload

4.3 Effect of Distance between Traffic Signs

The results in Table 4.3 show that travel time was significantly influenced by changing the distances between traffic signs, $F(2,1392) = 257.576$, $p < 0.001$, with the shortest travel time for 25% reduction in distances (M=86.48, SD=9.37) and the longest travel time for 25% increase in the distances between traffic signs (M=112.51s, SD=12.97). However, changing the distances between traffic signs has no significant effects on the speed, $F(2,1392) = 2.334$, $p > 0.05$, and percent maximum braking force, $F(2,1392) = 2.422$, $p > 0.05$.

Table 4.3 Sign distance effect on descriptive statistics and the level of significance for physical and self-reported measures of workload variables

Measures	25% Reduction		Standard		25% Increase		Difference (p value)
	Mean	SD	Mean	SD	Mean	SD	
Travel time (s)	86.487	9.370	101.575	30.169	112.519	12.976	<0.001**
Speed (mph)	52.051	7.912	51.730	7.706	51.159	7.078	0.171
Percent maximum braking force (%)	4.255	10.754	3.168	7.934	3.273	10.094	0.156
Location of changing lane (ft)	-308.013	1760.227	-710.665	2074.349	-1451.417	2820.975	<0.001**
Mental demand (%)	32.830	27.223	29.284	27.073	31.000	27.577	0.598
Physical demand (%)	15.258	15.298	14.364	15.214	15.409	15.436	0.847
Temporal demand (%)	30.470	26.728	27.277	25.659	28.106	25.242	0.606
Performance (%)	19.428	19.285	17.712	18.702	19.125	18.747	0.756
Effort (%)	25.477	25.980	25.644	26.727	26.924	26.738	0.899
Frustration (%)	14.504	16.661	13.557	16.411	14.212	15.782	0.899
Total Workload (%)	26.902	20.961	24.886	20.455	26.060	20.508	0.747

* $p < 0.05$

** $p < 0.01$

Results of the location of changing lanes with respect to three distance levels between traffic signs show that there were significant differences between the locations of changing lanes. A post-hoc Tukey test revealed that the locations of changing lane in the standard distance and 25%

reduction in the distance between traffic signs were significantly lower compared to the location of changing lane in 25% increase in the distance between traffic signs ($p < 0.05$).

The univariate analysis of variance showed no significant difference in workload measurements due to the change of distance between traffic signs. Changing the distance between traffic signs, as Figure 4.3 shows, leads to an increase in participants' self-reported workloads. Decreasing the standard distance between traffic signs by 25% resulted in a 12.1% increase in mental demand; 6.2% increase in physical demand; 11.7% increase in temporal demand, 9.6% increase in performance and 6.9% increase in the level of frustration. Effort with 6% decrease was the only scale that was reduced by reducing the sign distance. Overall, total workload was increased by 8%. Increasing the standard sign distance had a similar effect on participants' perceived workload. The largest difference, when the distances were increased by 25%, was observed in performance with 7.9 percent increase in the workload level. Frustration increased by 4.8% when sign distance was increased. However, total workload with only 4.7 % increase was not affected as much by increasing the sign distance. Similar to merge effect, mental demand was the most dominant workload scale, and frustration and physical demand were the least. Overall, all self-reported measures of workload variables were lower in standard sign distance which suggests that the present sign distance is optimal and any change in distance negatively affects perceived workload.

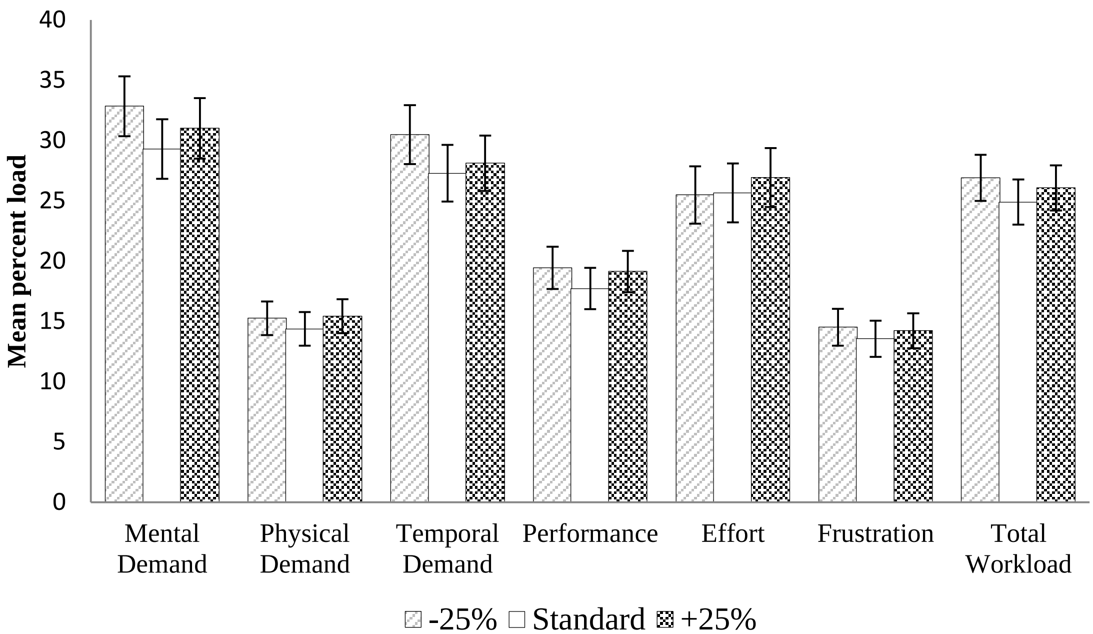

Figure 4.3 Effects of changing the distance between traffic signs on workload

4.4 Effect of Zones

The results of univariate analysis of variance showed that there were significant differences in speed of vehicles, $F(3, 1392) = 156.507$, $p < 0.001$ and percent maximum braking force, $F(3, 1392) = 129.554$, $p < 0.001$ within four defined zones in the merge configurations. Post-hoc Tukey test results revealed that the mean speed and percent maximum braking force in the advance warning zone were significantly different (higher) from those of in other zones. The drop in the mean speed of vehicles in the transition zone suggest that on average, all vehicles complied with the posted speed of 50 mph and maintained this speed through the rest of the work zone. The largest reduction in speed was observed between advance warning zone and transition zone with 13% drop in the mean speed. With respect to percent maximum braking force, participants in the advance warning zone applied more braking force compared to the other zones. The braking pattern shows a drastic decline in braking force in the transition zone followed by a slight increase in the buffer. The percent maximum braking force in the JLM configuration was lower than the CLM in all zones and reached its minimum (M= .01%, SD=.14) in the work zone. This implies that with respect to braking force, participants going through the JLM experienced a smoother drive with less braking in the work zone.

Table 4.4 Zone effect on speed and percent maximum braking force

	Speed (mph)		Difference (p value)	Percent maximum braking force (%)		Difference (p value)
	Mean	SD		Mean	SD	
Advance warning zone	58.012	7.683	<0.001**	11.025	14.475	<0.001**
Transition zone	50.222	7.371		0.565	4.151	
Buffer	49.243	6.016		2.402	8.081	
Work zone	49.110	5.068		0.268	2.459	

* p <0.05
** p < 0.01

4.5 Relationship between Self-Reported Measures of Workload Variables and Physical Driving Variables

A series of Pearson correlations were calculated in order to determine the association among the self-reported measures of workload variables and physical driving variables. The participants' self-reported measures of workload for mental demand, temporal demand, performance, effort, frustration and total workload were not related to travel time, speed, percent maximum braking force and location of changing lane, $p > 0.05$. However, physical demand was positively related to speed $r(9) = 0.173$, $p < 0.001$, and percent maximum braking force $r(9) = 0.155$, $p < 0.05$. Physical demand was negatively related to the location of changing lane $r(9) = -0.116$, $p < 0.05$. The higher physical demand participants perceived, the more likely they were to remain in the closed lane longer.

Table 4.5 Pearson correlation between self-reported measures of workload variables and physical driving variables

	Travel Time	Speed	Braking Force	Location of Merge
5. Mental Demand	0.062	-0.067	0.050	0.025
6. Physical Demand	-0.047	0.173**	0.155*	-0.116*
7. Temporal Demand	0.007	0.051	0.004	0.002
8. Performance	-0.048	0.071	0.037	-0.068
9. Effort	-0.003	0.010	0.052	-0.003
10. Frustration	-0.052	0.076	0.039	-0.035
11. Total Workload	-0.018	0.037	0.055	-0.008

* p <0.05
** p < 0.01

4.6 Effects of Covariates

To assess the effect of covariates on travel time, speed, percent maximum braking force and self-reported workloads two MANCOVA tests were conducted with gender, years of driving experience, previous traffic violation, aggressiveness and personality entered into the model as covariates. MANCOVA I tests the effects of covariates on physical driving variables and MANCOVA II tests the effects of covariates on self-reported workload. MANCOVA I results for gender, Wilks' Lambda= 0.946,F(3,1385)= 26.466, p <0.001, years of driving experience, Wilks' Lambda=.978, F(3,1385)= 10.432, p <0.001, previous traffic offense experience, Wilks' Lambda= 0.993, F(3,1385)= 3.436, $p < 0.05$, personality, Wilks' Lambda=0.976, F(3, 1385)= 8.505, $p < 0.001$ and aggressiveness, Wilks' Lambda=0.994, F(3, 1385) = 2.914, p <0.05 were statistically significant. MANCOVA II results for all covariates were significant ($p < 0.001$), indicating the workload is influenced by all gender, years of driving experience, previous traffic offense experience, personality and aggressiveness.

4.6.1 Effect of gender

Male participants with the mean travel time of 101.48 second (SD=24.38) differed significantly from females with the mean travel time of 96.64 seconds (SD=15.22), F(1,1387) = 18.905, $p < 0.001$. The effect of gender difference on speed and braking force suggest that female participants had 4% higher speed, F(1, 1387)= 46.220, p <0.001 and exerted 76% more braking force than males, F(1,1387)= 38.634, p <0.001. Gender has a significant effect on the location of changing lanes, F(1,339)=9.429, p <0.05. On average, male participants tend to remain in the closed lane longer. Females with 32.7%, as opposed to males with 23.47%, experienced 39.55% more total workload. The largest difference between male and female participants belongs to effort with female expending 96.3% more effort. However, the results show that female participants with the average of 12.03% for frustration were less frustrated than males with the average of 14.83%.

4.6.2 Effect of years of driving experience

The results of univariate analysis of variance show that driving experience does not influence travel time and speed. However, it influenced percent maximum braking force, F(1,1387)= 24.392, p <0.001 and location of changing lane, F(1,1387)=138.912, $p < 0.001$. A post hoc Tukey test comparing the percent maximum braking force of the participants revealed that those with one to three years of driving experience (M=2.17%, SD=5.84) differed significantly from those with more than three years of experience (M=5.02%, SD=12.34), $p < 0.001$. Drivers with less than a year of driving experience showed to change lane three times earlier than those with more than one year of driving experience. Results indicate that years of driving experience was related to mental demand, physical demand, performance, and frustration. Participants with less than a year of driving experience had significantly more frustration than either those with two to years of driving experience, or the ones with more than three years of driving experience. Moreover, participants with less than a year of driving experience had a weaker performance than either those with two to years of driving experience or the ones with more than three years of driving experience. However, no significant differences were found in the total workload of participants with less than a year of driving with those with higher years of driving experience ($p > .05$).

4.6.3 Effect of Previous Traffic Offense Experience

Travel time, F(1,1387)=3.955, $p < 0.05$, percent maximum braking force, F(1,1387)= 5.406, $p < 0.05$, and location of changing lane, F(1,339)=4.303, $p < 0.05$, were influenced by previous traffic offense experience. However, no significant effect was found for speed, F(1,1423)=0.037, $p > 0.05$. Those with traffic offense experience (M=99.25, SD.15.81) had 3% lower travel time than those without traffic offense (M=102.38, SD=32.94). In terms of percent maximum braking force, participants with previous traffic offense experience (M=4.10, SD=10.94) exerted 78% more braking force than those without any offense experience (M=2.30, SD=5.52). With respect to location of changing lanes, traffic offenders change their lanes 37% earlier than non-traffic offenders. On average, participants with traffic offense history experienced 7% more total workload compared to those who did not have any traffic violation records. For participants with previous traffic offense experience, mental demand, temporal demand and performance were 12%, 17.1% and 19.5% higher, respectively. On the contrary, participants without any traffic offense experience exerted 15.2% more effort and experienced 87.4 % more frustration.

4.6.4 Effect of Aggressiveness

No significant differences were found in the mean travel time and speed. However, aggressiveness influenced percent maximum braking force, F(1,1387)= 8.147, $p < 0.05$ and location of changing, F(1,339)=17.098, $p < 0.00.1$ The results show that participants with aggressive personality (M=1.94, SD=4.95) exerted 49% less braking force compared to non aggressive participants, (M=3.81, SD=10.18).In terms of location of changing lanes, aggressive participants remained in the closed lane significantly longer than non-aggressive ones.
Analysis of effects of aggressiveness on workload shows that, except for the effort, for the rest of NASA TLX scales, participants with low aggressiveness experienced more workload. Although, according to frustration–aggression hypothesis, aggression is the result of frustration, the results show that aggressive participants were 75% less frustrated than non-aggressive ones while driving through the work zone.

4.6.5 Effect of Personality

Significant differences were found between type A and B personalities in travel time, F(1,1387) = 8.871, $p < 0.05$, speed, F(1,1387) = 27.506, $p < 0.001$, and percent braking force, F(1,1387) = 8.872, $p < 0.05$. However, no statistically significant difference was found in location of changing lanes between type A and B participants. Type B participants traveled though the work zone on average 3% faster and exerted 62.5% more force on the brake pedal than type A participants.
Type A personalities with the mean of 26% for total workload (SD = 22) did not differ significantly from type B personalities with the mean of 25% (SD=25.2). However, type B personalities experienced 29.7% and 32.7% more physical demand and frustration respectively. Self-reported measures for type B personalities performed 26% better. Overall, both personality types experienced lower workload under the JLM configuration. Total workloads for type A and B personalities were 21% and 6% lower respectively under the JLM configuration. Further analysis suggests that the performance of both personalities were much better under the JLM and thus joint merge configuration is more advantageous than the conventional one.

4.7 Stepwise Multiple Regression Model

Stepwise multiple regression analysis was conducted , taking gender, years of driving experience, previous traffic offense, personality type, DBQ measures (aggressive violations, ordinary violations, lapses and errors) and DAX measures (verbal aggressiveness, physical aggressiveness, vehicular aggressiveness and adaptive behavior) as independent variables and travel time, speed, percent maximum braking force, location of changing lanes and NASA TLX self-reported measures of workload variables (mental demand, physical demand, temporal demand, performance, effort, frustration and total workload), as dependent variables. The critical values for model entry and removal were $p = .05$ and $p = .01$, respectively. Multicollinearity diagnostics suggested adequate independence of predictors (all tolerance levels <0.80).

4.7.1 Speed

The model for speed consists of 14 variables as shown in Table 4.6. The multiple correlation coefficients was 0.580, indicating approximately 33.6% of the variance of the speed could be accounted for by zone, adaptive behavior, traffic, physical aggressiveness, gender, previous traffic violation, verbal aggressiveness, aggressive violations, lapses, merge, distance, personality, vehicle aggressiveness and error, $F(14,1425) = 51.504$, $p < 0.001$. The T square changes for zone, adaptive behavior, and traffic were 0.167, 0.036 and 0.032 respectively, which all together comprise 69% of the total R square of the model. Years of driving experience ($t = -1.377$, $p > 0.05$) and ordinary violations ($t = 0.995$, $p > 0.05$), were not significantly correlated with speed and were excluded from the model at step 14 of the analysis.

4.7.2 Percent maximum braking force

In the model for percent maximum braking force, the results revealed that, after 14 steps, correlation coefficients in this model was .472, indicating approximately 22.2% of the variance of percent maximum braking force could be explained by zone, years of driving experience, gender, personality, vehicular aggressiveness, adaptive behavior, merge, traffic, previous traffic violations, and verbal aggressiveness, $F(14, 1425) = 29.121$, $p < 0.001$. The zone variable with 55% contribution to the total R square of the model was the most significant variable. Years of driving experience and gender with 9% and 5% contribution, respectively were in the second and third place. Ordinary violations ($t = -1.007$, $p > 0.05$), and distance ($t = -1.776$, $p > 0.05$) did not have any significant contribution to the model and were excluded at step 14.

4.7.3 Travel time

The analysis of the model for travel time revealed that correlation coefficients in this model was .666, indicating approximately 44.3% of the variance of travel time could be accounted for by distance, merge, years of driving experience, adaptive behavior, physical aggressiveness, previous traffic violation, verbal aggressiveness, vehicle aggressiveness, gender, and personality, $F(10,1429) = 113.614$, $p < 0.001$. Distance with .225 and merge with .149 R square changes were the most significant variables explaining 50% and 35.5% of the variance in the model, respectively. The excluded variables in this model were all DAX measures, aggressive violation ($t = 0.346$, $p > 0.05$), ordinary violations ($t = -1.328$, $p > 0.05$), error ($t = -0.573$, $p > 0.05$), lapses ($t = -.678$, $p > 0.05$), and traffic density ($t = -.168$, $p > 0.05$).

4.7.4 Location of changing lanes

Years of driving experience, vehicular aggressiveness, distance between traffic signs, gender, physical aggressiveness, merge configuration, and previous traffic violation were the independent variables used in the model for effort, $F(7,352)= 13.196$, $p < 0.001$. The model resulted in the correlation coefficients of 0.456 which explained 20.8% of the variance in the merging distance from the transition zone. Years of driving experience, vehicular aggressiveness and distance with 30% 23% and 19% contribution to the overall R square were the most significant variables in the model. The rest of the 18 variables were not correlated with effort ($p > 0.05$) and therefore, were excluded from the model at step seven.

Table 4.6 Summary of stepwise multiple regression model for traffic variables

Model 1: Speed $R = 0.580$; $R^2= 0.336$; Adjusted $R^2= 0.329$; Std. Err. = 6.204; $p < 0.001$					
	B	Standard Error	β	*t*	sig.
(Constant)	66.449	2.138		31.076	<0.001
Zone	-2.768	0.146	-0.409	-18.929	<0.001
Adaptive Behavior	-0.287	0.028	-0.260	-1.104	<0.001
Traffic	2.672	0.327	0.176	8.170	<0.001
Physical Aggressiveness	-0.477	0.075	-0.164	-6.383	<0.001
Gender	2.903	0.409	0.169	7.101	<0.001
Previous Traffic Violation	-2.078	0.467	-0.126	-4.449	<0.001
Verbal Aggressiveness	0.307	0.045	0.267	6.759	<0.001
Aggressive Violations	-0.420	0.145	-0.092	-2.890	0.004
Lapses	0.265	0.060	0.139	4.404	<0.001
Merge Configuration	-0.758	0.327	-0.050	-2.317	0.021
Distance between Traffic Signs	-0.446	0.200	-0.048	-2.227	0.026
Personality	1.522	0.424	0.100	3.593	<0.001
Vehicular Aggressiveness	-0.286	0.087	-0.143	-3.282	0.001
Error	-0.210	0.077	-0.092	-2.746	0.006

Table 4.6 (Continued)

Model 2: Percent Maximum Braking Force

R = 0.472; R^2= 0.222; Adjusted R^2= 0.215; Std. Err. = 8.572; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	21.184	3.244		6.530	<0.001
Zone	-3.043	0.202	-0.352	-15.061	<0.001
Years of Driving Experience	1.419	0.297	0.117	4.782	<0.001
Gender	3.584	0.565	0.164	6.343	<0.001
Personality	2.594	0.586	0.133	4.428	<0.001
Vehicular Aggressiveness	-0.635	0.121	-0.248	-5.234	<0.001
Adaptive Behavior	-0.262	0.040	-0.185	-6.570	<0.001
Merge Configuration	-1.464	0.452	-0.076	-3.239	<0.001
Traffic	-1.346	0.452	-0.070	-2.979	0.003
Previous Traffic Violation	-2.700	0.645	-0.128	-4.183	<0.001
Verbal Aggressiveness	0.205	0.063	0.139	3.255	0.001
Physical Aggressiveness	-0.286	0.104	-0.077	-2.741	0.006
Aggressive Violations	0.657	0.201	0.113	3.262	0.001
Error	-0.461	0.106	-0.157	-4.351	<0.001
Lapses	0.325	0.083	0.134	3.914	<0.001

Model 3: Travel Time

R = 0.666; R^2= 0.443; Adjusted R^2= 0.439; Std. Err. =16.784; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	18.193	6.024		3.020	0.003
Distance Between Traffic Signs	13.016	0.542	0.474	24.026	<0.001
Merge Configuration	17.277	0.885	0.386	19.530	<0.001
Years of Driving Experience	3.487	0.579	0.125	6.020	<0.001
Adaptive Behavior	0.521	0.073	0.159	7.161	<0.001
Physical Aggressiveness	0.526	0.202	0.061	2.609	0.009
Previous Traffic Violation	7.235	1.220	0.148	5.931	<0.001
Verbal Aggressiveness	-0.953	0.121	-0.279	-7.896	<0.001
Vehicular Aggressiveness	1.511	0.217	0.255	6.953	<0.001
Adaptive Behavior	-5.501	1.086	-0.109	-5.065	<0.001
Personality	-3.409	1.043	-0.075	-3.269	0001

Model 4: Location of changing lanes

R = 0.456; R^2= 0.208; Adjusted R^2= 0.192; Std. Err. =631.657; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	-1984.284	311.871		-6.363	<0.001
Years of Driving Experience	28.074	42.877	0.319	6.532	<0.001
Vehicular Aggressiveness	47.318	1.318	0.255	4.586	<0.001
Distance between Traffic Signs	-174.255	4.773	-0.203	-4.274	<0.001
Gender	-226.496	81.240	-0.143	-2.788	0.006
Physical Aggressiveness	32.117	14.062	0.119	2.284	0.023
Merge Configuration	164.949	66.583	0.118	2.477	0.014
Previous Traffic Violation	152.883	74.868	0.100	2.042	0.042

4.7.5 Mental demand

The model for mental demand consists of 10 variables as shown in Table 4.7. The multiple correlation coefficients was 0.614, indicating approximately 37.7% of the variance of the mental demand could be accounted for by lapses, error, previous traffic violation, traffic, verbal aggressiveness, gender, adaptive behavior, vehicular aggressiveness, years of driving experience, and merge configuration, $F(10,349) = 21.135$, $p < 0.001$. However, personality ($t = 0.237$, $p > 0.05$), physical aggressiveness ($t = -1.228$, $p > 0.05$), aggressive violations ($t = 0.740$, $p > 0.05$) ordinary violations ($t = -0.536$, $p > 0.05$) and distance between traffic signs ($t = -0.649$, $p > 0.05$) were not significantly correlated with mental demand and did not enter into the equation at step 10 of the analysis.

4.7.6 Physical demand

The multiple correlation coefficients in the model for physical demand was 0.569, indicating approximately 32.3% of the variance of physical demand could be accounted for by aggressive violations, lapses, error, ordinary violations, traffic, verbal aggressiveness, gender, vehicular aggressiveness, and physical aggressiveness, $F(9,350) = 18.576$, $p < 0.001$. Driving experience ($t = 0.203$, $p > 0.05$), previous traffic violations ($t = -1.758$, $p > 0.05$), personality type ($t = -.219$, $p > 0.05$), adaptive behavior ($t = 1.183$, $p > 0.05$), merge configuration ($t = 0.432$, $p > 0.05$) and the distance between traffic signs ($t = 0.092$, $p > 0.05$), were not significantly correlated with physical demand and were excluded from the model.

4.7.7 Temporal demand

The analysis of the model for temporal demand revealed that correlation coefficients in this model was .425, indicating approximately 18% of the variance of temporal demand could be accounted for by lapses, merge, previous traffic offense, verbal aggressiveness, traffic, adaptive behavior, and vehicular aggressiveness, $F(7,352) = 11.054$, $p < 0.001$. The rest of independent variables were not significantly correlated with temporal demand and were excluded from the model.

4.7.8 Performance

In the model for performance, the results revealed that , after 12 steps, correlation coefficients in this model was .462, indicating approximately 21.3% of the variance of performance could be explained by adaptive behavior, gender, physical aggressiveness, lapses, error, merge configuration, vehicular aggressiveness, and previous traffic violation driving, $F(8,351) = 11.890$, $p < 0.001$. Years of driving experience ($t = -1.758$, $p > 0.05$), personality ($t = -1.372$, $p > 0.05$), verbal aggressiveness ($t = 0.073$, $p > 0.05$), aggressive violations ($t = 1.712$, $p > 0.05$), ordinary violations ($t = -1.311$, $p > 0.05$), traffic density ($t = -1.425$, $p > 0.05$), and distance ($t = -0.138$, $p > 0.05$) did not have any significant contribution to the model for performance.

4.7.9 Effort

Gender, adaptive behavior, lapses, physical aggressiveness, error and traffic were the independent variables used in the model for effort, $F(6,343)= 34.93$, $p < 0.001$, with the correlation coefficients of .610 R^2 of .373. Gender and adaptive behavior with 0.112 and 0.154 R square changes, respectively contributed the most to the final R square of the model. The rest of the variables were not correlated with effort ($p > 0.05$) and therefore, were excluded from the model at step six.

4.7.10 Frustration

In the model for frustration; lapses, aggressive violations, merge configuration, traffic and adaptive behavior were the five predictors which had significant correlation with frustration, $F(5,354)= 19.237$, $p < 0.001$. The correlation coefficient of 0.462, overall, explained 21.4% of the variability within frustration, $F(5,354)= 19.237$, $p < 0.001$. Lapses with 0.086, aggressive violations with 0.077 R square changes, contributed the most to the model total R square. The rest of the variables were not correlated with effort ($p > 0.05$) and therefore, were excluded from the model at step five.

4.7.11 Total Workload

The model for total workload consisted of 10 steps. The multiple correlation coefficients for this model was .625, indicating approximately 39.1% of the variance of total workload could be accounted for by lapses, error, gender, adaptive behavior, previous traffic violation, verbal aggressiveness, traffic, physical aggressiveness, vehicular aggressiveness and merge, $F(10,349)= 22.373$, $p <0.001$. Lapses with 0.111 R square change was the most significant variable associated with total workload followed by gender and error with 0.061 and 0.067 R square change, respectively. Years of driving experience ($t = 0.812$, $p > 0.05$), personality ($t = 0.560$, $p > 0.05$), aggressive violations ($t = 0.096$, $p > 0.05$) and ordinary violations ($t = 0.340$, $p > 0.05$) and distance between traffic signs ($t = -0.399$, $p > 0.05$) were not significant predictors of total workload and therefore excluded from the model at step 1.

Table 4.7 Summary of stepwise multiple regression models for NASA TLX Subcomponents

Model 1: Mental Demand

R = 0.614; R^2= 0.377; Adjusted R^2= 0.359; Std. Err. = 21.814; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	6.569	12.858		0.511	0.610
Lapses	4.203	0.411	0.613	1.221	<0.001
Error	-2.212	0.488	-0.269	-4.534	<0.001
Previous Traffic Violation	-18.025	3.029	-0.303	-5.951	<0.001
Traffic	-8.515	2.299	-0.156	-3.703	<0.001
Verbal Aggressiveness	-1.642	0.307	-0.396	-5.357	<0.001
Gender	8.539	2.851	0.139	2.996	0.003
Adaptive Behavior	0.796	0.192	0.200	4.147	<0.001
Vehicular Aggressiveness	2.058	0.535	0.286	3.845	<0.001
Years of Driving Experience	5.023	1.492	0.148	3.367	0.001
Merge	-5.545	2.299	-0.102	-2.412	0.016

Model 2: Physical Demand

R = 0.569; R^2= 0.323; Adjusted R^2= 0.306; Std. Err. = 12.731; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	26.998	5.278		5.116	<0.001
Aggressive Violations	-1.638	0.526	-0.179	-3.116	0.002
Lapses	1.815	0.233	0.473	7.805	<0.001
Error	-3.069	0.378	-0.664	-8.110	<0.001
Ordinary Violations	1.321	0.223	0.432	5.933	<0.001
Traffic	-4.899	1.342	-0.161	-3.651	<0.001
Verbal Aggressiveness	-0.719	0.164	-0.309	-4.391	<0.001
Gender	4.515	1.673	0.131	2.699	0.007
Vehicular Aggressiveness	0.878	0.316	0.218	2.777	0.006
Physical Aggressiveness	-0.685	0.330	-0.117	-2.074	0.039

Model 3: Temporal Demand

R = 0.425; R^2= 0.180; Adjusted R^2= 0.164; Std. Err. = 23.634; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	38.119	11.817		3.226	0.001
Lapses	1.944	0.342	0.299	5.684	<0.001
Merge	-7.603	2.491	-0.147	-3.052	0.002
Previous Traffic Offense	-15.649	3.265	-0.278	-4.793	<0.001
Verbal Aggressiveness	-1.197	0.327	-0.305	-3.661	<0.001
Traffic	-6.453	2.491	-0.125	-2.590	0.010
Adaptive Behavior	0.574	0.204	0.152	2.820	0.005
Vehicular Aggressiveness	1.294	0.554	0.190	2.336	0.020

Table 4.7(Continued).

Model 4: Performance
R = 0.462; R^2= 0.213; Adjusted R^2= 0.195; Std. Err. =16.932; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	17.644	8.830		1.998	0.046
Adaptive Behavior	0.562	0.146	0.204	3.858	<0.001
Gender	12.637	2.220	0.296	5.692	<0.001
Physical Aggressiveness	-0.683	0.384	-0.094	-1.778	0.076
Lapses	1.720	0.318	0.362	5.399	<0.001
Error	-1.584	0.376	-0.278	-4.211	<0.001
Merge	-3.904	1.785	-0.104	-2.187	0.029
Vehicular Aggressiveness	-0.798	0.291	-0.160	-2.737	0.007
Previous Traffic Violation	-7.188	2.103	-0.175	-3.417	0.001

Model 5: Effort
R = 0.610; R^2= 0.373; Adjusted R^2= 0.362; Std. Err. = 21.103; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	-24.161	1.290		-2.348	0.019
Gender	28.906	2.669	0.485	1.829	<0.001
Adaptive Behavior	1.147	0.175	0.298	6.536	<0.001
Lapses	2.461	0.391	0.371	6.295	<0.001
Physical Aggressiveness	-2.141	0.454	-0.212	-4.720	<0.001
Error	-2.038	0.464	-0.255	-4.396	<0.001
Traffic	-5.606	2.225	-0.106	-2.520	0.012

Model 6: Frustration
R = 0.462; R^2= 0.214; Adjusted R^2= 0.203; Std. Err. = 14.509; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	11.965	5.710		2.095	0.037
Lapses	1.479	0.206	0.362	7.175	<0.001
Aggressive Violations	-2.791	0.484	-0.286	-5.770	<0.001
Merge	-4.591	1.529	-0.141	-3.002	0.003
Traffic	-4.343	1.529	-0.134	-2.840	0.005
Adaptive Behavior	0.266	0.114	0.112	2.336	0.020

Model 7: Total Workload
R = 0.625; R^2= 0.391; Adjusted R^2= 0.373; Std. Err. = 16.310; $p < 0.001$

	B	Standard Error	β	*t*	sig.
(Constant)	2.510	9.202		2.229	0.026
Lapses	2.932	0.309	0.566	9.503	<0.001
Error	-2.154	0.366	-0.346	-5.885	<0.001
Gender	14.878	2.140	0.320	6.953	<0.001
Adaptive Behavior	0.788	0.144	0.262	5.481	<0.001
Previous Traffic Violation	-11.007	2.269	-0.245	-4.852	<0.001
Verbal Aggressiveness	-1.042	0.232	-0.333	-4.491	<0.001
Traffic	-5.809	1.719	-0.141	-3.379	0.001
Physical Aggressiveness	-1.373	0.375	-0.174	-3.660	<0.001
Vehicular Aggressiveness	1.333	0.417	0.245	3.197	0.002
Merge	-4.298	1.719	-0.104	-2.500	0.013

This page is intentionally left blank.

5 SUMMARY AND CONCLUSION

The present study was carried out to determine the effects of merge configuration, traffic flow levels and the distance between traffic signs on driver behavior and self-reported measures of workload variables. Furthermore, we investigated how individual differences may affect driving behavior in work zones.

5.1 Merge Configuration

The comparative analysis of travel time between two merge configurations revealed that driving through the JLM takes more time. This is due to the fact that in the JLM, more signs are incorporated in the advance warning zone and thus the length of this zone is longer than that of in the CLM.The results of our study have congruent validity with the study conducted by Idewu and Wolshon [24], in which no statistically significant differences in speed were found between the CLM and JLM. On average, drivers in both configurations complied with the posted speed limit of 50 mph.

The results show that overall, both male and female participants exerted less force on the brake pedal under the JLM configuration. Several possible explanations to this can be suggested. One of the factors contributing to the superiority of JLM over CLM is the omission of right of way from the open lane. According to work zone crash data, 54.2% of accidents in work zones with road closure are sideswipe collisions and rear-end crashes [18]. Unlike JLM, in Conventional Lane Merge, drivers in an open lane have the right of way while those in the closed lane should adjust their speed and merge to the open lane when they find enough gaps. When vehicles in the closed lane perform an early merge, drivers in both lanes would have enough time to adjust their speed and distance and consequently complete the zipping action. However, when drivers in the closed lane perform late merge, which requires more effort to change lanes, they would experience higher temporal demand. This scenario is not true for the JLM, as drivers in both lanes have equal right of way and merge in alternating manner.Ishak *et al.* [5]compared the CLM and JLM with respect to uncomfortable deceleration which has a direct relationship with braking. They found that CLM configuration exhibited less uncomfortable decelerations than the JLM configuration for the advance warning area. However, for low to moderate flow rates the JLM configuration had less frequent rate of uncomfortable decelerations and therefore was considered safer than the CLM configuration.

The comparison of two merge configurations with respect to the location of changing lanes suggest that overall, the JLM configuration encourages drivers to remain in the closed lane more. One explanation to this can be the use of "BOTH LANE MERGE" sign in the advance warning zone. The use of this sign obviates drivers from performing redundant lane change which might be futile. As a result, we hypothesize that drivers prefer to remain in their lanes and wait for further instructions by the traffic signs. Merging early during congested periods presents the undesirable situation of one lane being over utilized and the other being underutilized. Such conditions have been linked to the problems of long queues, aggressive driving and delays at work zone entrances.

In terms of effects of work zone configurations on perceived driving workload, the results suggest that JLM requires less workload. Participants going through the JLM completed the experiments with less difficulty and lower time pressure associated with other merging vehicles. On average, female participant experienced higher workload when driving through simulated work zones. Similar results regarding higher effort ratings by female drivers were reported by Hancock [59]. JLM has a significant positive effect on temporal demand which is the time pressure associated with the rate or pace of merging maneuvers. The results show that participants going through the JLM had 25% less temporal demand. This suggests that as opposed to CLM, JLM configuration improves driver's performance and reduces the negative effects of merging maneuvers such as stress and fear of colliding with merging vehicles.

5.2 Traffic Density

Although the number of cars in high traffic density was twice as many as in low traffic density, no traffic jam or bottleneck was formed in the transition and work zones. As a result no significant difference in travel time between two levels of traffic density was found. However, as expected, higher mean speed and lower percent maximum braking force in the low traffic density was observed. Participants in low traffic density remained in the closed lane longer. Traffic density has a significant influence on a participant's perceived workload. The results show that lower traffic density results in lower workload for all scales. On average, participants driving in the scenarios with low traffic densities experienced 20% lower total workload and had better subjective ratings for performance. The findings show that mental demand followed by temporal demand and effort were the three major contributors to the total workload in different levels of traffic density. The largest differences between workloads in high and low traffic densities were observed in physical demand, frustration and mental demand with 28%, 26% and 24% reduction in workload, respectively in low traffic density. Similar results were found by Shinar [60] in which congested roads led to frustration and more aggressive driving behavior. Similarly, the results of a study by Lajunen *et al.* [61] showed that exposure to driving during the rush-hour correlated with ordinary violations among both men and women. These findings suggest that rather than driver aggression, deliberate risky driving is positively related to exposure to congestion.

5.3 Distance between Traffic Signs

Experienced drivers look where they expect relevant information to be, resulting in an effective search if their expectations were correct [62]. Martens [63] showed that people fail to notice unexpected information or show increased response times to unexpected information. In the driving context, several studies considered expectation as a crucial factor influencing reaction times [41]. The self-reported years of driving experience shows that about 47% of participants had more than three years of driving experience. Analysis of self-reported measures of workload variables shows that our results corroborate with Evans's findings [41]. On average participants finished the tasks with lower total workload when signs were placed at their expected locations (standard distance). Reducing the distance between traffic sign requires a driver to process more information in less amount of time and this increases the difficulty level of the task and leads to information overload, whereas increasing the distance requires a driver to look for the signs in unexpected places. Groff and Chaparro [64] stated that individuals use a schema along with their own experience to guide the allocation of attention to both the objects and features they consider most relevant to the task. In reality, changing sign distance violates driver's schema and as a result drivers experience insecurity. This will consequently lead to increase in the stress level and difficulty in accomplishing the driving task. Thus, changing the distance between signs creates more frustration and requires more effort from a driver to accomplish the task. It was anticipated that by reducing the distance between traffic signs, drivers would have less time to process the data and this would negatively affect their mental and temporal demand ratings. The principle factor contributing to the increase in mental and temporal demand ratings is the feeling of being under pressure due to the pace of experiment. In order to compensate for time pressure, drivers can either slow down to find more time to read the signs or speed up to finish the task. According to Hancock [59] there is a negative correlation between the time demand and safety, suggesting that drivers either have a preference for being on schedule , and thus tend to pay less attention to the demand, in this case "driving safely", or have a preference for driving safely, and therefore pay less attention to the demand of staying on schedule. Nevertheless, neither increasing nor decreasing the distance between traffic signs improved drivers' workload.

5.4 Zones

The results show that except for the advance warning zone, there is minimal variation in speed and percent braking force in other zones. Advance warning zone is an area to warn motorists of an upcoming work zone and a possible lane closure and a significant drop in speed was expected in this zone. Efficient use of traffic control devices so that the advance warning areas of work zones operate as planned is crucial. The results show that the application of more traffic signs in this zone significantly affects speed and braking pattern. The inter-zonal analysis of mean speed of vehicles showed that, the mean speed in the advance warning zone in the JLM configuration (M=56.86 mph, SD=5.61) was 3.8% lower than the mean speed in the corresponding zone in the CLM (M=59.16 mph, SD=9.16). This is due to the application of SPEED ZONE AHEAD and LANE CLOSED AHEAD signs at 3200 ft and 1500 ft, respectively prior to the transition zone. The braking pattern shows a drastic decline in braking force in the transition zone followed by a slight increase in the buffer. The percent maximum braking force in the JLM configuration was lower than the CLM in all zones and reached its minimum (M= .01%, SD=.14) in the work zone

5.5 Effect of Covariates

The analysis of results with respect to gender showed that male participants drove with 6% and 3% lower speed in the CLM and JLM, respectively. Overall, female participants exerted more force on the brake pedal and had 4.19% less travel time. Female participants tended to change lanes sooner when they encountered a work zone and they experienced 39.55% more total workload. The analysis of results with respect to personality shows that participants with type A personality, people who are hard driving, ambitious and time conscious, as opposed to type B, drove through the CLM and JLM with 6.3% and 0.1% less speed respectively and showed to remain in the closed lane longer. Type B participants traveled through both the CLM and JLM with 3.7% less travel time. The results showed that participants with aggressive personalities drove 2% faster than low aggressive participants. Aggressive people tended to exert less braking force, finished the experiment faster and experienced less workload. In a study on lane-changing behavior, Sun and Elefteriadou [65] found four factors which were frequently considered by drivers before changing lanes. These factors are speed advantage, aggressiveness, consideration of consequences and degree of selfishness. Our findings are similar to those of Sun and Elefteriadou [65] and show that aggressiveness is one of the major factors influencing the location of changing lane. An interesting finding of this study is that participants with previous traffic offenses had 3% shorter travel time, exerted 78% more braking force and experienced 7% more total workload than those without any offense experience. Results indicated that participants with less than a year of driving experience had significantly more frustration than those with two to years of driving experience or more. Furthermore, the results shows that driving experience influenced percent maximum braking force and location of changing lanes and those with one to three years of driving exerted 56% lower braking force compared to those with more than three years of experience

5.6 Recommendations

The results of this experiment did show significant differences in braking force and location of changing lanes between the CLM and JLM. Drivers in the JML exert less braking force and remain in the closed lane longer. The lower reported workload measures in the JLM suggest that the JLM is more conducive to driving. The modification of a few elements such as number of signage in the traffic control plan of the joint merge and the length of transition zone may yield more results in terms of difference in speed. Moreover, since the JLM is a new concept to many drivers, it is expected that the learning curve will affect the results in a more favorable way.

In conclusion, by comparing the results of physical driving variables and studying the human factor analysis we found conclusive evidence that Joint Lane Merge outperforms the Conventional Lane Merge in terms of…(FILL IN). However, the results obtained in this study are related to day time driving. Due to the drop in the visual acuity of drivers at night time or rainy weather, the JLM may yield different results in different environments. Thus, future studies should focus on studying the operational performance of the JLM under those situations.

6 References

1. WSDOT. *Washington State Department of Transportation*. 2013 [cited 2013 June 6th]; Available from: http://www.wsdot.wa.gov/Projects/QuieterPavement/CommonQuestions.htm.
2. Dissanayake, S. and S.R. Akepati, *Identification of Work Zone Crash Characteristics*, 2009, Iowa Department of Transportation: Manhattan, KS.
3. U.S. Department of Transportation, *Moving Ahead: The American Public Speaks on Roadways and Transportation Communities*, 2001, Federal Highway Administration: Washington D.C.
4. U.S. Department of Transportation, *Meeting the Customer's Needs for Mobility and Safety during Construction and Maintenance Operations*, 1998, Federal Highway Administration: Washington, D.C.
5. Ishak, S., et al., *Safety Evaluation of Joint and Conventional Lane Merge Configurations for Freeway Work Zones.* Traffic Injury Prevention, 2012. **13**: p. 208-212.
6. U.S. Department of Transportation, *Manual on uniform traffic control devices for streets and highways*, 2009, Federal Highway Adminstration: Washington, D.C.
7. Rouphail , N.M., et al., *Comparative Study of Short-and Long Term Urban Freeway Work Zones*, in *Transportation Research Record: Journal of Transportation Research Board* 1988. p. 4-14.
8. Beacher, A.G., et al., *Guidelines for Using Late Merge Traffic Control in Work Zones:Results of a simulation based study.* Transportation Research Record: Journal of the Transportation Research Board, 2005. **1911**: p. 42-50.
9. Rayaprolu, P., et al., *Operational Assessment of Joint and Conventional Lane Merge Configurations for Freeway Work Zones.* Journal of Intelligent Transportation Systems, 2013: p. null-null.
10. Bai, Y. and Y. Li, *Determining the Major Causes of Highway Work Zone Accidents in Kansas*, 2006: Kansas.
11. Hirsch, P., *Adolescent driver risk taking and driver education: Evidence of a mobility bias in public policymaking.* Journal of Safety Research, 2003. **34**(3): p. 289-298.
12. Mayhew, D.R., *Driver education and graduated licensing in North America: Past, present, and future.* Journal of Safety Research, 2007. **38**(2): p. 229-235.
13. U.S. Department of Transportation. *National Strategy to Reduce Congestion on America's Transportation Network*. 2006 [cited 2013 July 19]; Available from: http://isddc.dot.gov/OLPFiles/OST/012988.pdf.
14. U.S. Department of Energy, *Temporary Losses of Highway Capacity and Impacts On Performance*, 2002, Oak Ridge National Laboratory: Knoxville, Tennessee.
15. Schrank, D., et al., *2011 Urban Mobility Report* 2011, Texas Transportation Institute: Texas.
16. Ullman, G.L., *Characteristics of Today's Work Zone*, 2004, Transportation Research Board: Washington D.C.
17. National Center for Statistics and Analysis, *Traffic Safety Facts 2010*, 2010, U.S. Department of Transportation: Washington, DC
18. Ullman, G.L., et al., *Traffic Safety Evaluation of Nighttime and Daytime Work Zones*, 2008.

19. Bureau of Labor Statistics. *Census of Fatal Occupational Injuries* 2012 [cited 2013 August 22]; Available from: http://stats.bls.gov/iif/oshcfoi1.htm.
20. Jiang, Y., *Traffic Capacity, Speed, and Queue-Discharge Rate of Indiana's Four-Lane Freeway Work Zones.* Transportation Research Record: Journal of the Transportation Research Board, 2007. **1657**: p. 10-17.
21. Pesti, G., et al., *Traffic Flow Characteristics of the Late Merge Work Zone Control Strategy.* Transportation Research Record: Journal of the Transportation Research Board, 1999. **1657**: p. 1-9.
22. Grillo , L.F., et al., *Evaluation of the dynamic late lane merge system at freeway construction work zones.* Transportation Research Record: Journal of Transportation Research Board 2008. **2055**: p. 3 – 10.
23. Kang , K.P., et al., *Dynamic late merge control at highway work zones: evaluations, observations, and suggestions.* Transportation Research Record: Journal of the Transportation Research Board, 2006. **1948**: p. 86-95.
24. Idewu, W.I.A. and B. Wolshon, *Joint Merge and Its Impact on Merging Speeds in Lane Reduction Areas of Construction Zone.* Transportation Research Record: Journal of the Transportation Research Board, 2010. **2169**: p. 31–39.
25. McCoy, P.T. and G. Pesti, *Dynamic Late Merge Control Concept for Work Zones on Rural Interstate Highways.* Transportation Research Record: Journal of the Transportation Research Board, 2001. **1745**: p. 20-26.
26. Yi, H. and T.E. Mulinazzi, *Urban freeway onramp invasive-influences on mainline operations.* Transportation Research Record: Journal of the Transportation Research Board, 2007. **2023**: p. 112-119.
27. Steele, D.A. and W.R. Vavrik, *Improving the Safety of Moving Lane Closures*, 2009, Illinois Center for Transportation.
28. Makigami, Y., et al., *Merging lane length for expressway improvement plan in Japan.* Journal of Transportation Engineering, 1988. **114**(6): p. 718–734.
29. Ahammed, M.A., et al., *Modeling driver behavior and safety on freeway merging areas.* Journal of Transportation Engineering, 2008. **134**(9): p. 370–377.
30. Al-Kaisy, A. and F. Hall, *Guidelines for Estimating Freeway Capacity at Long Term Reconstruction Zones.* Journal of Transportation Engineering, 2002. **129**(5): p. 572–577.
31. Rayaprolu, P., *Operational And Safety Assessment Of Joint And Conventional Lane Merge Configurations For Freeway Work Zones*, in *The Department of Civil and Environmental Engineering*2010, Louisiana State University and Agricultural and Mechanical College.
32. Rouphail, N. and G. Tiawari, *Flow characteristics at freeway lane closures.* transportation Research Record: Journal of the Transportation Research Board, 1985. **1035**: p. 50–58.
33. Tarko, A., et al., *Modeling and Optimization of the Indiana Lane Merge Control System on Approaches to Freeway Work Zones*, 1998, Joint Transportation Research Program: Purdue University.
34. Kang, K.P., et al., *Dynamic late merge control at highway work zones: evaluations, observations, and suggestions.* Transportation Research Record-Journal of Transportation Research Board, 2006. **1948**: p. 86-95.

35. Grillo, L.F., et al., *Evaluation of the Dynamic Late Lane Merge System at Freeway Construction Work Zones.* Transportation Research Record-Journal of Transportation Research Board, 2008. **2055**: p. 3-10.
36. Dijker, T. and P.H. Bovy, *Influencing Lane Changes at Lane Drops*, in *78th Annual Meeting of the Transportation Research Board* 1998, National Research Council: Washington, DC.
37. Feldblum, E., et al., *Alternate Merge Sign at Signalized Intersections*, in *Research Report: SPR-2233*2005, Connecticuit Department of Transportation: Rocky Hill.
38. Idewu, W.I.A., *Evaluation of Conventional and Unconventional Lane Reductions in Urbanized Areas*, in *Department of Civil and Environmental Engineering*2006, Louisiana State University.
39. Schrock, C.F. and K. McClure, *Crash Analysis of Work-Zone Lane Closures with Left-Hand Merge and Downstream Lane Shift*, 2009. p. 10-19.
40. Bureau of Transportation Statistics, *State Transportation Statistics 2011*, 2011, U.S. Department of Transportation, Researchand Innovative Technology Administration: Washington,DC.
41. Evans, L., *Traffic safety*. 2004, Bloomfield Hills, MI: Science Serving Society.
42. Reason, J., et al., *Errors and violations on the roads: a real distinction?* Ergonomics, 1990. **31**: p. 1315–1332.
43. Ulleberg, P. and T. Rundmo, *Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers.* Safety Science, 2003. **41**: p. 427–443.
44. Weng, J. and Q. Meng, *Effects of environment, vehicle and driver characteristics on risky driving behavior at work zones.* Safety Science, 2012. **50**(4): p. 1034-1042.
45. Yagil, D., *Gender and age-related differences in attitudes toward traffic laws and traffic violations.* Transportation Research Part F: Traffic Psychology and Behaviour, 1998. **1**(2): p. 123-135.
46. Chliaoutakis, J.E., et al., *Aggressive behavior while driving as predictor of self-reported car crashes.* Journal of Safety Research, 2002. **33**(4): p. 431-443.
47. Chen, C.-F., *Personality, safety attitudes and risky driving behaviors—Evidence from young Taiwanese motorcyclists.* Accident Analysis & Prevention, 2009. **41**(5): p. 963-968.
48. Wickens, C.D. and J.G. Hollands, *Engineering Psychology and Human Performance*. 3rd ed. 2000, Upper Saddle River, New York: Prentice Hall.
49. Hart, S.G. and L.E. Staveland, Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research, in Advances in Psychology, P.A. Hancock and N. Meshkati, 1988, North-Holland, p. 139-183
50. Deffenbacher, J.L., et al., *The Driving Anger Expression Inventory: a measure of how people express their anger on the road.* Behaviour Research and Therapy, 2002. **40**(6): p. 717-737.
51. Bortner, R.W., *A short rating scale as a potential measure of pattern A behaviour.* Journal of Chronic Diseases, 1969. **22**: p. 87-91.
52. Hart, S.G. and L.E. Staveland, *Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research*, 1988.
53. Constantinou, E., et al., *Risky and aggressive driving in young adults: Personality matters.* Accident Analysis & Prevention, 2011. **43**(4): p. 1323-1331.

54. Bass, C., *Type A behaviour in patients with chest pain: Test-retest reliability and psychometric correlates of Bortner scale.* Journal of Psychosomatic Research, 1984. **28**(4): p. 289-300.
55. Kennedy, R.S., et al., *Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness.* The International Journal of Aviation Psychology, 1993. **3**(3): p. 203-220.
56. IBM Corp, *IBM SPSS Statistics for Windows,*, 2012, IBM Corp: Armonk, NY.
57. Minitab Inc, *Minitab 16 Statistical Software*, 2010, Minitab Inc: State College, PA.
58. Yeo, I.-K. and R.A. Johnson, *A new family of power transformations to improve normality or symmetry.* Biometrika, 2000. **87**(4): p. 954–959.
59. Hancock, P.A., *The effect of performance failure and task demand on the perception of mental workload.* Applied Ergonomics, 1989. **20**(3): p. 197-205.
60. Shinar, D., *Aggressive driving: the contribution of the drivers and the situation.* Transportation Research Part F: Traffic Psychology and Behaviour, 1998. **1**(2): p. 137-160.
61. Lajunen, T., et al., *Does traffic congestion increase driver aggression?* Transportation Research Part F: Traffic Psychology and Behaviour, 1999. **2**(4): p. 225-236.
62. Meyers, L.S. and R.W. Rhoades, *Visual search of common scenes.* Quarterly Journal of Experimental Psychology, 1978. **30**(297–310).
63. Martens, M.H., *Stimuli fixation and manual response as a function of expectancies.* Human Factors, 2004. **46**(3): p. 410–423.
64. Groff, L.S. and A. Chaparro, *Effects of experience and task relevance on the ability to detect changes in a real-world task*, in *Human factors and ergonomics society 47th annual meeting*2003. p. 1605–1609.
65. Sun, D. and L. Elefteriadou, *Lane-changing behavior on urban streets: A focus group-based study.* Applied Ergonomics, 2011. **42**(5): p. 682-691.

7 APPENDIX A FORMS AND QUESTIONNAIRE

7.1 Informed Consent Form

Study Title
To study the effect of changing driving conditions on driver behavior towards design of safe and efficient traffic system.

Performance site
Louisiana State University. Full sized LSU driving simulator housed in LSU driving simulator lab in the Department of Civil and Environmental Engineering. Location:Room 2225 Patrick F. Taylor Hall.

Investigators
Dr. FereydounAghazadeh, Professor, MIE, (225) 578-5367, 2155 Patrick Taylor Hall, aghazadeh@lsu.edu
Dr. Laura Ikuma, Assistant Professor, MIE, (225) 578 5364, 2156- Patrick F. Taylor Hall, likuma@lsu.edu

Co-Investigators
Mahmoud Shakouri, MIE, Graduate Student, (225) 436-4666, mshako1@tigers.lsu.edu
KarthyPunniaraj, MIE, Graduate Student, (225) 349-6755, kpunni1@tigers.lsu.edu

Purpose of the Study
The purpose of this study is to:

1. To determine the effects of traffic patterns and traffic flow levels on driver behavior.
2. To demonstrate the use of human factors analysis techniques applied to the understanding of driver behavior and performance.

Subject Inclusion
Primarily students, both male and female, from Louisiana State University (LSU), ages 18-60 with a valid driving license.

Exclusion Criteria
Individuals that have the following conditions:

1. One who does not have a valid driving license.
2. One who is prone to or show motion sickness

Number of Subjects: 20

Study Procedures
You will first read this consent form and be given a verbal explanation and a study procedure of the project. If you agree to the terms of participation, sign this form which shows your interest and willingness to participate in the project. At any time during the experiment, if more than normal task operating discomfort is encountered, please cease activity.

Benefits
There are no direct benefits; but this experiment may provide information that will yield future improvements in the task of designing and planning to move towards an optimum driving behavior. That will in turn reduce congestions, increase speed and capacity of the roads, satisfied drivers who facilitate emergency evacuations etc.

Risks/Discomforts
The only risk is the chances of getting motion sickness. The tasks have been designed to fall within the normal job performance for a good driving condition, so the potential physical or mental discomfort is not expected to be any greater than that, after a typical video game. Participants are encouraged to inform the investigators or the co-investigators, if motion sickness is felt.

Right to Refuse: At any time during the experiment, you have the right to not participate or withdraw from the study. There will be no penalties for withdrawal.

Privacy:
Other than as set forth above, participant identity will remain confidential unless disclosure is legally compelled.
Results of the study may be published, but no names or identifying information will be included in the publication.

Financial Information: No costs are incurred by subjects in this study.

Removal: You are expected to comply with the investigator's instructions. If you fail to comply, you will be removed by an investigator from the experiment.

Signatures: The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about participant's rights or other concerns, I can contact Robert C. Mathews, Chairman, Institutional Review Board, (225) 578-8692. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of the consent form.

____________________________________ __________________
Subject Signature Date

____
Print name

7.2 Demographic Information Form

Directions

Please fill an appropriate box for each question.

1. Sex ☐ Male ☐ Female

2. Age <20☐ 20-2☐ 30-3☐ 40-4☐ ≥50☐

3. How long have you had your driving license? ------------------

4. What is your driving experience?

☐ <1 ☐ 1-5 ☐ 5-9 ☐ ≥10

5.Estimate the number of miles you drive each year ---------------------

6. During the past year (12 months) have you been involved in any accidents?

☐ Yes ☐ No

7. If yes, how many accidents --------------------

8. During the past year (12 months) have you had any highway violations?

☐ Yes ☐ No

9. If yes, how many violations -----------------------------

10.How often do you talk on your cell phone when you drive?

☐ Never ☐ Sometimes ☐ Always

11. How often do you text message when you drive?

☐ Never ☐ Sometimes ☐ Always

7.3 Driving Anger Inventory (DAX)

Directions

Read each statement and then tick in the box to the right of the statement indicating how often you generally react or behave in the manner described when you are angry or furious while driving. There are no right or wrong answers. Do not spend too much time on any one statement.

		Almost Never	Some-times	Often	Always
1	I give the other driver the finger.				
2	I drive right up on the other driver's bumper.				
3	I drive a little faster than I was.				
4	I try to cut in front of the other driver.				
5	I call the other driver names aloud.				
6	I make negative comments about the other driver				
7	I follow right behind the other driver for a long time.				
8	I try to get out of the car and tell the other driver off.				
9	I yell questions like "Where did you get your license?"				
10	I roll down the window to help communicate my anger.				
11	I glare at the other driver.				
12	I shake my fist at the other driver.				
13	I stick my tongue out at the other driver.				
14	I call the other driver names under my breath.				
15	I speed up to frustrate the other driver.				
16	I purposely block the other driver from doing what he/she wants to do.				
17	I bump the other driver's bumper with mine.				
18	I go crazy behind the wheel.				
19	I leave my lights on in the other driver's rear view mirror.				
20	I try to force the other driver to the side of the road.				
21	I try to scare the other driver.				
22	I do to other drivers what they did to me.				
23	I pay even closer attention to being a safe driver.				
24	I think about things that distract me from thinking about the other driver.				

		Almost Never	Some-times	Often	Always
25	I think things through before I respond.				
26	I try to think of positive solutions to deal with the situation.				
27	I drive a lot faster than I was.				
28	I swear at the other driver aloud.				
29	I tell myself its not worth getting all mad about.				
30	I decide not to stoop to their level.				
31	I swear at the other driver under my breath.				
32	I turn on the radio or music to calm down.				
33	I flash my lights at the other driver.				
34	I make hostile gestures other than giving the finger.				
35	I try to think of positive things to do.				
36	I tell myself it's not worth getting involved in.				
37	I shake my head at the other driver.				
38	I yell at the other driver.				
39	I make negative comments about the other driver under my breath.				
40	I give the other driver a dirty look.				
41	I try to get out of the car and have a physical fight with the other driver.				
42	I just try to accept that there are bad drivers on the road.				
43	I think things like "Where did you get your license?"				
44	I do things like take deep breaths to calm down.				

		Almost Never	Some-times	Ofte n	Alwa ys
45	I just try and accept that there are frustrating situations while driving.				
46	I slow down to frustrate the other driver.				
47	I think about things that distract me from the frustration on the road.				
48	I tell myself to ignore it.				
49	I pay even closer attention to other’s driving to avoid accidents.				

7.4 Manchester Driving Behavior (DBQ)

Directions:
Please show the frequency by filling the corresponding number.

1=Never 2=Hardly Ever 3=Occasionally 4=Quite Often 5=Frequently 6=Nearly All The Time

Begin each question with "**How often do you**"

Aggressive Violations		1	2	3	4	5	6
7	Sound your horn to indicate your annoyance to another road user						
17	Become angered by another driver and give chase with the intention of giving him/her a piece of your mind						
25	Become angered by a certain type of a driver and indicate your hostility by whatever means you can						

"Ordinary" Violations		1	2	3	4	5	6
10	Pull out of a junction so far that the driver with right of way has to stop and let you out						
11	Disregard the speed limit on a residential road						
18	Stay in a motorway lane that you know will be closed ahead until the last minute before forcing your way into the other lane						
20	Overtake a slow driver on the inside						
21	Race away from traffic lights with the intention of beating the driver next to you						
23	Drive so close to the car in front that it would be difficult to stop in an emergency						
24	Cross a junction knowing that the traffic lights have already turned against you						
28	Disregard the speed limit on a motorway						

1=Never 2=Hardly Ever 3=Occasionally 4=Quite Often 5=Frequently 6=Nearly All The Time							
Errors		1	2	3	4	5	6
5	Queuing to turn left onto a main road, you pay such close attention to the main stream of traffic that you nearly hit the car in front of you						
6	Fail to notice that pedestrians are crossing when turning into a side street from a main road						
8	Fail to check your rear-view mirror before pulling out, changing lanes, etc.						
9	Brake too quickly on a slippery road or steer the wrong way in a skid.						
13	On turning left nearly hit a cyclist who has come up on your inside.						
14	Miss "Give Way" signs and narrowly avoid colliding with traffic having right of way.						
16	Attempt to overtake someone that you had not noticed to be signaling a right turn.						
17	Become angered by another driver and give chase with the intention of giving him/her a piece of your mind.						

Lapses		1	2	3	4	5	6
1	Hit something when reversing that you had not previously seen.						
2	Intending to drive to destination A, you "wake up" to find yourself on the road to destination B.						
4	Get into the wrong lane approaching a roundabout or a junction.						
12	Switch one thing, such as the headlights, when you meant to switch on something else, such as the wipers.						
15	Attempt to drive away from the traffic lights in third gear.						
19	Forget where you left your car in a car park.						
22	Misread the signs and exit from a roundabout on the wrong road.						
26	Realize that you have no clear recollection of the road along which you have just been traveling.						

7.5 Bortner Personality Test

Directions: Each pair represents two extremes. Please mark with a vertical line where you fall, at either extreme or somewhere in the middle.

Never Late	|————|	Casual about appointments
Not competitive	|————|	Very competitive
Anticipates what others are going to say (nods, interrupts, finishes for them)	|————|	Good listener, hears others out
Always rushed	|————|	Never feels rushed, even under pressure
Can wait patiently	|————|	Impatient when waiting
Goes "all out"	|————|	Casual
Takes things one at a time	|————|	Tries to do many things at once, thinks about what one is going to do next
Emphatic in speech (may pound desk)	|————|	Slow, deliberate talker
Wants good job recognized by others	|————|	Only cares about satisfying self no matter what others may think
Fast (eating, walking, etc.)	|————|	Slow doing things
Easy going	|————|	Hard driving
"Sits" on feelings	|————|	Expresses feelings
Many interests	|————|	Few interests outside work/school
Satisfied with job	|————|	Ambitious

7.6 NASA TLX

NASA-TLX Descriptions

Refer to these descriptions as you complete the Workload Rating sheet.

Mental Demand: *Low/High* How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Physical Demand: *Low/High* How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Temporal Demand:*Low/High* How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Performance: *Excellent/Poor* How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Effort: *Low/High* How hard did you have to work (mentally and physically) to accomplish your level of performance?

Frustration Level: *Low/High* How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

Instructions: select the member of each pair that provided the most significant source of workload variation in these tasks.

#	Physical Demand	Mental Demand
1	Temporal Demand	Mental Demand
2	Temporal Demand	Physical Demand
3	Performance	Physical Demand
4	Temporal Demand	Frustration
5	Temporal Demand	Effort
6	Performance	Mental Demand
7	Frustration	Mental Demand
8	Effort	Mental Demand
9	Frustration	Physical Demand
10	Effort	Physical Demand
11	Temporal Demand	Performance
12	Performance	Frustration
13	Performance	Effort
14	Effort	Frustration

Workload Rating

Instructions: Place a vertical mark on each scale that represents the magnitude of each factor in the task you just performed.

Mental Demand

Low High

Physical Demand

Low High

Temporal Demand

Low High

Performance

Excellent Poor

Effort

Low High

Frustration Level

Low High

7.7 Motion Sickness Evaluation Form

Directions:
Please read the symptoms provided in the table below and tell us if any of those have. You can show the severity of the symptom by marking the corresponding number. 0 means you don't have that symptom and as the number goes up the severity increases proportionally.

Motion Sickness Assessment Questionnaire (MSAQ)											
Do you feel	**Not at all**										**Severely**
	0	1	2	3	4	5	6	7	8	9	10
Sick to stomach											
Faint-like											
Annoyed/irritated											
Sweaty											
Queasy											
Lightheaded											
Drowsy											
Clammy/cold sweat											
Disoriented											
Tired/fatigued											
Nauseated											
Hot/warm											
Dizzy											
Like I am spinning											
As if I might vomit											
Uneasy											