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Driver Response and Safety Effect of Three-foot Bicycle Passing Laws

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DRIVER RESPONSE AND SAFETY EFFECT OF THREE-FOOT BICYCLE PASSING LAWS

A Thesis
Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Master of Science
in
The Department of Civil and Environmental Engineering

by
Nelida A. Herrera
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ABSTRACT

The long and tragic history of vehicle-bicycle crashes in the United States has increasingly led to calls for legislative action to provide greater protection and comfort for bicyclists on the nation’s roadways. Among the most common of these actions are the three-foot passing laws. Recent history suggests that these laws may contribute to reducing the number of vehicular/bicycle-related collisions as well as their accompanying deaths and injuries, but few, if any, studies have shown how they substantively affect driver behavior. This thesis builds upon the results of recent research quantifying the effects of the three-foot passing laws by comparing key behavioral aspects of drivers aware and unaware of these requirements. The research, conducted in a full-scale driving simulator, also examined the response of participants under different scenarios of opposing traffic volume. Driver actions and vehicle movements relative to a bicyclist were measured in terms of lateral distance and speed at the time of overtaking. Driving simulators have not been previously used in the study overtaking behavior. Therefore, this represents a unique opportunity to assess the use of a driving simulator as a tool to study this behavior.

Awareness of the three-foot passing laws did not significantly affect the driving behavior of study participants. This was evidenced from a comparison made between the mean overtaking distances provided by participants unaware and aware of the law showing that the overtaking distances were not significantly different. The presence of various opposing traffic volume scenarios was not found to affect driver behavior significantly. When investigating the ability of drivers to estimate the average lateral overtaking distance provided, it was noted that participants made close estimates of the mean lateral distances provided in the simulation. This suggests that the ability to measure lateral distances was not an issue for them. Finally, the findings of this
research show the valuable use of a driving simulator to model the behavior of drivers overtaking bicyclists. The approach used in this research can be used as a basis for conducting future studies by expanding the factors explored in this study.
CHAPTER 1. INTRODUCTION

Increasing traffic congestion and environmental concerns have motivated governmental agencies to emphasize the use of alternative modes of transportation. Among these modes, bicycling has increased in popularity and has recently gained higher attention from the US government.

The US has seen a 62 percent increase bike commuting nationwide from 2000 to 2013 (1). While this increasing trend is favorable for promoting environmentally and economically healthier communities (2), the safety of bicyclists remains a concern on American roads. This can be evidenced on a trip and distance basis, in which bicyclists are more likely to be fatally injured than vehicle occupants (3). Over a 28-year period, bicyclist fatalities from traffic crashes in the US had been declining from a 2.3 percent high in 1975 to 1.4 percent of all traffic deaths in 2003 (4). In 2013, however, the reported fatalities were up to approximate two percent of all traffic deaths (5).

In general, bicycle/motor-vehicle collisions have been found to be a primary cause of bicyclist deaths (6) and statistics show that the occurrence of these collisions (fatal and non-fatal) varies with location. This can be evidenced in the study of Hunter et al. (1997) were 58 percent of all collisions occurred at crossing path locations and 36 percent when traveling in parallel paths. More recent safety data from the National Highway Traffic Safety Administration (NHTSA) revealed 57 percent of bicyclist fatalities occurring at non-intersection locations in 2013 (5). This leads to the question: what is happening at non-intersection locations? Crashes resulting from passing maneuvers (e.g. overtaking) at non-intersections have been examined in previous research. In the study of Hunter et al. (1997), approximately nine percent of collisions at parallel path resulted from overtaking maneuvers. A later study conducted by Kim et al.
(2007) found that 12 percent of total collisions resulted from overtaking maneuvers. Although, overtaking collisions between a motorist and a bicyclist have a low probability of occurrence, research has consistently found this collision type to have a significantly higher likelihood of resulting in severe or fatal injuries to bicyclists (when bicyclists travel in the same direction as drivers) (7,8,9). And this likelihood increases during nighttime (8).

Various efforts to educate bicyclists and motorists, increase enforcement, and encourage safety conscious driving have been made throughout the US to counter safety problems. Other efforts related to planning and engineering include the addition of bicycle infrastructure. The unfortunate reality is, however, that this option is not always feasible (i.e. due to funding limitations, right of way constraints, presence of driveways) on the vast majority of facilities where bicyclists and vehicles share the roadway. In these situations, countermeasures related to geometric design of the roadway, traffic control features, and roadway lighting can be implemented to increase bicycle safety. In addition to these actions, legislative strategies aimed at creating safer and more comfortable riding environments for bicyclists have been enacted both in the US and abroad.

Among the most popular strategies are the three-foot passing laws. In June 2014, 25 states and the District of Columbia had a three-foot passing law in their legislation (the first enacted in Wisconsin in 1973) (10). In general, these laws establish that motor vehicles overtaking or passing bicyclists, traveling in the same direction, shall do so by providing a minimum of three feet of lateral separation (10). Some differences exist among these laws. For example, the State of Louisiana, where this research was conducted, enacted a three-foot in 2009 stating the following:
The operator of a motor vehicle, when overtaking and passing a bicycle proceeding in the same direction on the roadway, shall exercise due care while the motor vehicle is passing the bicycle and shall leave a safe distance between the motor vehicle and the bicycle of not less than three feet and shall maintain such clearance until safely past the overtaken bicycle (11).

Another form of the law was enacted in Colorado. In its statue, it is indicated that the minimum three-foot separation shall be between the right side of the driver's vehicle, including all mirrors or other projections, and the left side of the bicyclist at all times (10). Very few forms of the three-foot passing laws include speed as an additional safety element. An example of this is the statue in the State New Hampshire which reads as follows:

Every driver of a vehicle, when approaching a bicyclist, shall insure the safety and protection of the bicyclist and shall exercise due care by leaving a reasonable and prudent distance between the vehicle and the bicycle. The distance shall be presumed to be reasonable and prudent if it is at least 3 feet when the vehicle is traveling at 30 miles per hour or less, with one additional foot of clearance required for every 10 miles per hour above 30 miles per hour (12).

The intent of these laws is to create a safer and more comfortable environment for bicyclists because it can provide the comfort needed for non-bicyclist to start bicycling (13); increase safety for bicyclists (10, 14); educate the drivers by providing guidelines on how to pass bicyclists (12, 14). Other reasons include recognizing that bicyclists are legitimate and vulnerable roadway users; and setting a standard for enforcement (12).

1.1 Research Motivation

Despite the expectation for improved safety, no research has been conducted to assess how well drivers understand and drive in response to these laws. For instance, does knowledge of the three-foot passing laws significantly affect driver behavior? Are drivers able to estimate
the distance they provide when overtaking? Do drivers comply with the law? If drivers comply with these laws, then what might be the cause of overtaking crashes? If drivers do not comply with the law, how can driver education and/or enforcement be improved? Similarly, there is very little understanding on how drivers interpret this law under varying traffic conditions (e.g. high, medium, and low). In this sense, the questions that arise include: how close/fast do drivers pass bicyclists when overtaking maneuvers occur in the presence of opposing traffic? Do overtaking distance and speed vary significantly under different traffic volume conditions? This research has been undertaken to answer and provide insights into these critical questions.

1.2 Research Objectives

The main goal of this research was to explore the effects of a three-foot passing law by comparing the response of the study participants who were aware and unaware of the law under low, medium, and high opposing traffic volume conditions in a simulation conducted with a full-scale driving simulator.

1.3 Scope

To undertake this research, a series of different opposing traffic volume conditions on a rural roadway were simulated in the Louisiana State University driving simulator. Traffic and roadway related conditions controlled in this study included:

- Roadway classification: Rural Two-Lane Undivided Roadway with no Shoulders,
- Roadway alignment: Straight Segment
- Roadway grade: Flat Surface
- Lane width: Standard lane Width of Twelve Feet,
• Speed limit: 45mph,

• Environment condition: Daylight and Dry Weather Conditions, and

• Opposing traffic Volume Conditions: High, Medium, and Low.

In addition to the data collected with the driving simulator, information was sought through the use of an entry and exit questionnaires.
CHAPTER 2. LITERATURE REVIEW

Relevant background information on the behavior of motorists overtaking bicyclists was reviewed as part of the research effort. The review also investigated the data collection methods that have been implemented to study driver overtaking behavior as well as the performance measures used to quantify this behavior. Lastly, driver’s behavioral patterns observed in previous studies were reviewed and are summarized in this chapter.

2.1 Defining Overtaking Collisions

In an effort to understand the factors that contribute to bicycle/motor-vehicle collisions, Cross and Fisher (1975) developed what evolved into the National Highway Traffic Safety Administration’s Accident Typing for Bicyclist Accidents. Their study consisted of an extensive review of official traffic accident data and interview of individuals involved in fatal and non-fatal collisions in rural and urban roadways of four areas in the US. Seven major crash types were identified and referred to as “problem classes” each of which was further classified in what are called “problem types”. Cross and Fisher (1975) concluded that the likelihood of fatal injuries varies among all types of bicycle/motor-vehicle collisions. Interestingly, collisions resulting from motorist overtaking bicyclists had the highest likelihood of fatally injuring bicyclists and accounted for 56 percent of all fatal crashes in rural areas. Furthermore, they determined that the likelihood of overtaking collisions is greatest during nighttime.

Overtaking is a type of passing maneuver. According to Cross and Fisher’s crash typology, an overtaking collision between a motor vehicle and a bicycle can result from (a) motorist not seeing the bicyclist; (b) motorist losing control of the vehicle; (c) counteractive evasive action from the motorist and the bicyclist; (d) motorist misjudges the space required to
pass; and (e) bicyclist weaving an obstruction on the path. Their data showed that most of the overtaking collisions observed in the data occurred when motorists did not see the bicyclist. In addition, this problem type alone accounted for almost 25 percent of all fatal crashes in their sample, followed by motorist losing control of the vehicle (4.2 percent fatal injuries), counteractive evasive action from the motorist and the bicyclist (2.4 percent fatal injuries), motorist misjudges the space required to pass (1.8 percent fatal injuries), and bicyclist weaving an obstruction on the path (0.6 percent fatal injuries). 4.2 percent of fatal collisions were classified as unknown. Cross and Fisher observed that more than 50 percent of the overtaking collisions occurred during nighttime involved bicycles with lighting standards existent at that time (7).

2.2 Response Measures in Overtaking Maneuvers

The behavior of drivers during overtaking maneuvers can be quantified using different performance measures. The most common variable studied in previous research is lateral offset or lateral separation. Prior research has described this offset in terms of lateral distance or lateral clearance. Lateral distance refers to the offset from the center of the bicycle to the right edge of the motor vehicle body (15). On the other hand, lateral clearance is a measurement of the distance from left handle bar of the bicycle to the farthest point of the side view mirror (15). Due to limitations in the measuring capabilities of the simulator, lateral distance instead of clearance was the variable collected in this study. For consistency, no distinction was made between lateral distance and clearance when presenting the findings of previous studies since the measurement used in these studies was not always specified. Instead, the general term lateral separation was used when describing the findings of previous studies.
Speed and size of the overtaking vehicle have been researched, in a lesser extent, in previous studies. These two variables in combination with lateral separation have been found to influence the amount of lateral force exerted on bicyclists by an overtaking vehicle. This force can cause instability or turn over depending on its magnitude (16). As a consequence, speed can be included as an additional performance measure not only because of the aerodynamic effect but also for the fact that higher vehicle speeds have been found to increase the likelihood of severely injuring bicyclists traveling in parallel paths (9,17,18). Furthermore, in the recent study conducted by Llorca et al. (2015), it was shown that both lateral distance and speed influence the subjective risk perception of bicyclists (15). For the stated reasons above, the study included vehicle speed at the time of overtaking in addition to lateral distance as measures of performance.

2.3 Data Collection Methods

Research exploring motorist/bicyclist interaction during overtaking events have been limited to the use of on-site video recordings (19, 20) and instrumented bicycles (15, 21, 22, 23, 24) collecting driver behavior on actual roadways.

2.3.1 Naturalistic Studies

Instrumented bicycles have been extensively used in previous studies. The bicycles used are equipped with different devices such as cameras, GPS, ultrasonic sensors, data loggers, and lasers which collect. Most of the studies have only obtained measurements related to lateral distance from their experiments (15, 21, 22, 23, 24, 25) and some of these studies have collected speed data in addition to distance (15, 24). Other variables such as traffic volume conditions on
the oncoming lane have been captured using this method (24). The instrumented bicycle is generally ridden by an investigator who is part of the research effort. This data collection method is very labor-intensive and is limited to certain study conditions including the following:

1- Low speed corridors to ensure the safety of the person riding the instrumented bicycle.
2- Roadway and traffic characteristics as well as overtaking vehicle type and bicyclist characteristics, but leaving out driver related information such as driver demographics and whether or not the drivers were aware of the minimum distance required when overtaking.

On-site cameras have been used alone in few studies to collect lateral distance on high-speed corridors (20). Data collected with instrumented bicycles can be improved can be combined with mounted cameras placed on-site to capture more variables (25).

2.3.2 Driving Simulators

Driving simulators have been an effective tool for traffic engineering in a variety of applications which have been shown to improve traffic operations and safety. Driving simulators allow the study of driver behavior as a controlled, safe, and inexpensive alternative to conventional experimentation. Significant advantages in terms of experimental control and data collection are provided by using this technology. There are two general categories of driving simulators, fixed-base and motion-base. Each have been used in a variety of applications including: (a) the study of human factors involved in the driving tasks (26), (b) the influence of mood altering substances such as alcohol and drugs (27,28), (c) the study of driving performance
of special populations such as the elderly, or young drivers (29, 30), (d) the design and assessment of in-vehicle systems like GPS (31), (e) the effects of distraction on driving performance (32), (f) and the impact of various bicycle facilities on driver behavior (33), to name a few. These applications demonstrate that driving simulators are an excellent tool for evaluating bicycle safety policy due to their application in safety, driver behavior, and human factors. Furthermore, high speed corridors which can result dangerous for naturalistic experiments using instrument bicycles can be studied using this technology and controlling for the driver’s awareness and understating of the three-foot passing laws can be accomplished using this technology.

2.4 Collecting Lateral Overtaking Distance and Speed

Determining the instant or time frame to measure lateral distance and speed varies among past research studies. For example, the study of Walker et al. (2007) and the later study of Parkin and Shackel (2014), conducted with instrumented bicycles, defined overtaking distance as the smallest lateral separation recorded when the vehicle was overtaking the bicycle. The study of Love et al. (2012) defined overtaking distances as the distance when the front tire of a motor vehicle crossed the perpendicular plane of the bicycle (identified using a camera that was mounted on the bicycle). With regards to overtaking speed, Parkin and Shackel (2014) defined it as the maximum speed recorded during the overtaking maneuver. In this research, lateral overtaking distance and speed was collected at the same instant. This instant was identified by watching a video recorded by the simulator that captured the trajectory ahead of the subject vehicle. Further explanation about this can be found in Chapter 4.
2.5 Factors Influencing Lateral Distance and Speed

Overtaking motorists show certain behavioral sensitivity to the characteristics of the bicyclists, characteristics of the roadway as well as opposing traffic volume conditions and oncoming vehicle type. Additionally, variability in the overtaking behavior has also been observed based on the type of overtaking vehicle. The following subsections explain each factor in detail.

2.5.1 Characteristics of the Bicyclist

Motorists are sensible to bicyclist characteristics. Lateral passing distances have been found to be smaller when the bicyclist appears to be male (19, 21, 34). Lateral distance has also been found to be smaller when the bicyclist was wearing a helmet (21). However, the findings were inconsistent with a later study as it was determined that no significant relationship existed between helmet usage and lateral overtaking distances (35). Riding position can also affect driver behavior. It has been argued that riding closer to the center of the lane allows for bicyclists being noticed by motorists. Behavioral data, however, has shown that the rider’s position on the roadway significantly affect vehicle lateral overtaking distances (19, 21, 25). Walker et al. (2007) conducted a field study to test the effect of rider’s position on the roadway by varying the rider’s position from 0.25 to 1.25 meters (0.82 to 4.10 feet) away from the curb. His results showed that lateral distances, measured from the rightmost point of the bicycle, decreased with an increase in the separation of the bicyclist from the curb (21).
2.5.2 Characteristics of the Roadway

With regards to roadway characteristics, various factors such as curb lane width, presence of on-street bicycle lanes, and traffic control features can affect the lateral passing distance observed. Smaller passing distances were observed when the lane width was smaller (19, 22). Love et al. (2012) analyzed vehicle passing distances using a bicycle-mounted camera in Baltimore, Maryland. This study found that higher lane width significantly increased vehicle lateral overtaking distances (i.e. 4.8 ft, 5 ft and 5.8 ft lateral distances on standard 10-ft, 11-ft and 12-ft wide lanes, respectively). Research evaluating the effect of on-street bicycle lanes has been inconsistent, although, they have been found to reduce variability in vehicle passing distance (36, 37). In England, Parkin and Meyers (20) found that vehicles provide smaller lateral overtaking distances on high-speed roadways (speed limits 40mph – 50mph) with bicycle lanes than without. Other studies conducted on low-speed roadways (speed < 40mph) concluded that in the presence of on-street bicycle lanes, vehicles provide larger passing distances in comparison to roadways without them (22, 23, 34). In the study of Mehta et al. (2015), a bicycle was equipped with a portable sensor and a video camera for real time data collection in the Kitchener-Waterloo region, Canada. The researchers recorded lateral overtaking distance during overtaking events in two-lane and four lane urban arterials (speed limit < 35mph) with and without on-street bicycle lanes. The presence of on-street bike lane was found to significantly increase lateral overtaking distances on both roadway types. Kay et al. (2014) recorded motorist overtaking events in two-lane rural roadways. This study determined that the bicycle warning sign (W11-1) combined with the “Share the Road” plaque (W16-1), shown in Figure 1, does not significantly influence lateral overtaking distance during an overtaking event. However, it was found that motor vehicles tended to change their lateral position by shifting to the left when the sign was present.
In addition, average vehicle speeds were slightly lower when the sign was present. According to Parkin and Shackel, (2014), roadways with absence of center line marking dividing opposing traffic flows, tended to have smaller overtaking speeds in urban roadways with speed limits of 20 and 30 mph. Furthermore, the study of Parkin and Shackel (2014) identified a strongly significant effect on overtaking speed when considering the speed limit in 30mph and 20 mph urban roadways, however, overtaking distances were not significantly different.

![Bicycle warning sign and “Share the Road” plaque](http://mutcd.fhwa.dot.gov/htm/2003r1/part9/fig9b-03-2_longdesc.htm)

**Figure 1:** Bicycle warning sign and “Share the Road” plaque

(Extracted from: http://mutcd.fhwa.dot.gov/htm/2003r1/part9/fig9b-03-2_longdesc.htm)

2.5.3 Opposing traffic Volume and Oncoming Vehicle Type

Motorist’s behavior before and during an overtaking event is affected by the presence of opposing traffic (15, 24, 25). Kay et al. (2014) found that the presence of opposing traffic on a two-lane rural roadway significantly reduced lateral overtaking distances by 0.83 feet. However, this study did not characterize lateral overtaking distances in the presence of varying traffic
conditions on the oncoming lane (light, medium and high traffic). Parkin and Shackel (2014) observed smaller lateral overtaking distances when oncoming vehicles were two or less seconds apart (4.43 ft or less) and oncoming vehicle type was found to have no significant effect on overtaking distances. In addition, 5-second gaps in the opposing traffic resulted in greater overtaking speeds.

2.5.4 Characteristics of the Overtaking Vehicle

When considering the effect of motor vehicle type on lateral distances, research has found that heavy vehicles (truck or buses) tend to provide the smallest lateral distance (15, 20, 21, 25) while motorcycles tend to provide the largest (34, 25). The probability of overtaking a bicycle within five feet or less was found to increase by 33.7 percent when large vehicles overtake and decrease by 8.8 percent when motorcycles overtake (25). This was also observed for bicyclists riding on bike lanes (20) and shoulders (15).
CHAPTER 3. METHODOLOGY

This chapter describes the environments used in the main experiment; how the volunteered participants were evaluated; and finally how the data were analyzed to quantify driving behavior.

3.1 Driving Simulator Environment Design

A full-sized, motion-base driving simulator is housed in the LSU Driving Simulator Lab at the Department of Civil and Environmental Engineering and is shown in Figure 2. This lab was developed to be a multi-use facility for interdisciplinary research, instruction, and training.

The LSU Driving Simulator Lab is equipped with multi-channel audio/visual system with a 180 degree display. The full-width automobile cab includes a windshield, driver and passenger seats, center console and dash, full instrumentation; control loaded steering; breaking and acceleration; rearview mirrors; and real-time motion simulation.

Figure 2: LSU driving simulator lab
The LSU Driving Simulator Lab also has a library of residential, urban, rural, commercial, industrial, highway, intersection and traffic control features; complete with autonomous, interactive ambient traffic, extensive, interaction scripted vehicle activity, variable roadway friction and weather effects, and data collection definitions. The scenario creation interface allows for customizable highway systems design tools which allow researchers to program various virtual simulation networks. For this research the library was used construct a segment of rural road.

The simulator package included the following four accompanying software:

1. SimCreator
2. SimVista
3. SimObserver
4. DataDistillery

The dynamics of the driving simulation cab can be modified with SimCreator which is the graphical simulation and modeling system that allows the placement and connection of multiple programing components such as algorithms and scripts.

SimVista was used to design the environments used in the experiment. Traffic and roadway related conditions controlled in this study included:

- **Roadway Classification**: Rural Two-Lane Undivided Roadway with no Shoulders,
- **Roadway Alignment**: Straight Segment
- **Lane Width**: Standard lane Width of Twelve Feet,
- **Speed Limit**: 45mph,
- Environment Condition: Daylight and Dry Weather Conditions, and
- Opposing traffic Volume Conditions: High, Medium, and Low.

Since the standard lane width use in roadway design is twelve feet, this was the width selected for the study. The absence of shoulders was chosen to model an environment where the bicyclist is sharing the road with vehicular traffic. As mentioned in the literature review, few studies have been conducted in rural areas and in high speed corridors, therefore, this research simulated a rural roadway. High speed limits are likely to have fewer, if any, bicyclists sharing the road, therefore, a speed limit of 45mph was chosen for this study.

Participants, regardless of experimental group, were evaluated in three distinct driving scenarios while passing three simulated male bicyclist traveling at 12.5 mph in the same direction as the subject vehicle. The location of the bicyclist on the roadway was chosen based on the typical range of riding position reported by the FHWA (38) and was simulated at approximately 2.6 ft. from the edge of the roadway. The scenarios were referred to as “high traffic”, “medium traffic”, and ‘low traffic”. The high traffic volume scenario, shown in Figure 3 simulated an hourly flow rate of approximately 1200 vph in the oncoming lane. An hourly flow rate of approximately 600 vph was modelled for the medium traffic scenario (Figure 4) and approximately 400 vph for the low traffic scenario (Figure 5). These traffic flows were chosen to differentiate the headways provided in each traffic scenario. No standard guidelines were used to assign these traffic flows.
Figure 3: “High traffic” scenario

Figure 4: “Medium traffic” scenario
3.2 Participant Recruitment and Experiment Procedure

Subjects between the ages of 18 and 65 with normal or corrected-to-normal vision and with a valid driver’s license were recruited. The recruitment process consisted of advertisement sent via email to local companies; by posting flyers around the LSU campus, and through personal contact in accordance with the university’s Institutional Review Board’s (IRB) standards.

First, participants were introduced to the driving simulator and were asked to sign a consent form. Next, the participants were then assigned into one experimental group: the No policy group or the Policy group. Random assignment to a group was accomplished by asking participants to flip a coin. Participants who obtained heads, were allocated in the No Policy group while those who obtained tails were assigned in the Policy group. The experimental case (i.e. the order in which the scenarios were presented to the participants) was also randomized. Participants were asked to roll a six sided dice. The experimental cases as were assigned to each face of the dice are shown in Table 1.
Next, participants were asked to complete a profile questionnaire to collect demographic and driving experience information about the participants. After completing the questionnaire, the participants would drive through a warm-up or pretrial run. As part of the pretrial run, participants were encouraged to slow down and switch lanes. This would allow them to become acclimated with the simulation instrumentation, vehicle handling, breaking, and overall feel for the virtual environment.

<table>
<thead>
<tr>
<th>Experimental Case</th>
<th>Order of Traffic Volume Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low Traffic - Medium Traffic – High Traffic</td>
</tr>
<tr>
<td>2</td>
<td>Low Traffic - High Traffic - Medium Traffic</td>
</tr>
<tr>
<td>3</td>
<td>High Traffic - Medium Traffic – Low Traffic</td>
</tr>
<tr>
<td>4</td>
<td>High Traffic – Low Traffic – Medium Traffic</td>
</tr>
<tr>
<td>5</td>
<td>Medium Traffic – High Traffic – Low Traffic</td>
</tr>
<tr>
<td>6</td>
<td>Medium Traffic – Low Traffic – High Traffic</td>
</tr>
</tbody>
</table>

The pretrial run simulated a segment of roadway different from the actual test environment and with no bicyclists present. To avoid possible imitation of the driver behavior of ambient vehicles, no leading vehicles were presented in the trial run or the main experiment.

Table 2 shows the summary of the characteristics of the participants used in this study. The total participant pool consisted of 40 subjects (29 males and 11 females) between ages 19 to 57 (mean=33.6; SD= 10.5). The No Policy group consisted of 20 subjects (12 males and 8
females), ranging in age from 19 to 49 years (mean = 32.9; SD = 10.24). The Policy group was comprised of 20 subjects (17 males and 3 females), ranging in age from 22 to 57 years (mean = 34.3; SD = 10.91). Driver experience was determined from the amount of time the driver has had his/her driver’s license. On average, driving experience in the participant pool was approximately 17 years (SD=11.4). This average was also observed for participants in each experimental group.

<table>
<thead>
<tr>
<th>Table 2: Summary of Information Obtained from the Profile Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experimental Group</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>No Policy</strong></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
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<tr>
<td><strong>Policy</strong></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Once the practice was completed, test subjects proceeded to begin the test run. Before starting, participants in each experimental group were given a different set of instructions.
Participants in the No Policy group were instructed the following:

For the experiment, you will be driving in a 45mph roadway. Drive as you would normally do, and if you would like to pass somebody, please feel free to do so whenever you feel comfortable.

Due to time constraints to conduct the experiment and to ensure that enough participants were aware of the law, participants in the Policy group were informed about the law by reading them the following script:

For the experiment, you will be driving in a 45mph roadway. Drive as you would normally do, and if you would like to pass somebody, please feel free to do so whenever you feel comfortable. Remember that in Louisiana there is a three-foot bicycle passing law, which requires drivers to leave at least three feet of lateral distance when passing or overtaking a bicyclist. Please keep this in mind when you drive today.

Each participant then proceeded to drive in the test environment. As the participants drove through it, they first encountered one scenario of opposing traffic (high, medium, or low). Shortly after, the driver would come upon a bicyclist in the roadway in the presence of the corresponding opposing traffic scenario. In general, it was observed that as the participants approached the bicyclist, they would reduce speed, then wait for an acceptable gap in the opposing traffic and proceed to pass the bicyclist. The participants would then continue down the roadway as the opposing traffic dissipated. At this point the participant progressed into the second scenario, were opposing traffic would again pick up and the driver was soon behind another bicyclist. In total each participate passed three bicyclist, one during each of the three traffic scenarios. Between scenarios, participants drove through a stretch of the segment of roadway to allow for adjusting the speed before encountering the next bicyclist.
Upon completion of the test, participants were asked to fill out an exit questionnaire. This questionnaire was used to inquire about the perceived lateral overtaking distance provided when they overtook the bicyclist. In addition, this questionnaire was used to determine if the test subject was aware of the three-foot bicycle passing law prior to beginning the experiment. If participants in the No Policy group answered yes, they were removed from the subject pool. In this fashion, 13 subjects were removed from the participant pool. Also there were four additional participants who withdrew from the study due to motion sickness.

Participants completed their involvement in the experiment after completion of the exit survey. They were thanked for their time and contribution and were escorted out of the simulator lab.

3.3 Data Processing

After completing the experiment phase, the data collected during the simulation was extracted from SimObserver. This software collects and delivers the data in four different output files: a video file, log file, event file, and DAT file. The DAT file contains variables such as speed, lane position, pitch, headway distance, lateral acceleration, and road offset measured during the entire simulation. This file comes in .dat format which can be accessed with EXCEL to analyze and organize the data. Before analyzing and organizing the data in EXCEL, the time of overtaking was identified using DataDistillery. This software compiled the video and data captured with SimObserver in the same interphase as shown in Figure 6. In this manner, both the video and the variables collected were linked; therefore, they were reviewed at the same time. For this study, the time of overtaking was identified by watching the video capturing the path ahead of the subject (located at the top right hand corner of the video interphase in Figure 6).
Figure 7 shows the sequence of events that led to an overtaking event. Lateral overtaking distance and speed was extracted at the time immediately after the bicycle was no longer visible in the sequence. This approximately represented the time at which the entire body of the bicyclist was next to the vehicle. The process to identify of the time of overtaking was done in this fashion because no code was found to collect this data in the time allocated for the design of the experiment. This approach was similar to the one used in the study of Love et al. (2012) where
overtaking distance were extracted when the front tire of a motor vehicle crossed the perpendicular plane of the bicycle (identified using a camera that was mounted on the bicycle).

Figure 7: Video sequence used to identify the time of overtaking for each participant

Since the video logs and the spreadsheet are linked, measurements of road offset and speed were extracted from the simulator after the time of overtaking was identified. The value of road offset extracted from the simulator represented the position of the center of mass of the
vehicle relative to the center of the roadway. A negative number indicates that the center of mass of the subject vehicle is on the left lane while a positive number indicates a vehicle on the right lane.

Considering that the subject vehicle simulated in the experiment was approximately 5.6 ft wide (as indicated by the software developers), and that the center of mass of the bicycle was located at 2.6 ft from the curb, the lateral distance between the right edge of the vehicle and the center of mass of the bicycle was computed as shown in Figure 8.

![Diagram showing computation of lateral overtaking distance](image)

Figure 8: Diagram showing computation of lateral overtaking distance (not to scale)
CHAPTER 4. DISCUSSION OF RESULTS

Table 3 presents a summary of overtaking lateral distance and speed by traffic scenario and experimental group. A total of 120 overtaking events were recorded and analyzed. From these events, 60 were collected from the No Policy group (20 participants x 3 scenarios) and an additional 60 from the Policy group (20 participants x 3 scenarios).

4.1 Effect of the three-foot bicycle passing laws

With regards to the effect of the awareness of the law on the overtaking behavior of the subject participants, it was hypothesized that:

1- The mean lateral overtaking distances provided by participants aware and unaware of the law were not the same.

2- The mean overtaking speeds of participants aware or unaware of the law were not the same.

To test these hypotheses, a two-way analysis of variance (ANOVA) was performed at a five percent level of significance ($\alpha=0.05$) and the results are presented in the following subsections.

4.1.1 Lateral Overtaking Distance

Overall, violations of the minimum three-foot lateral separation requirement were observed for both the No Policy (2.48 ft) and the Policy group (1.22 ft). Maximum distances of 11.54 ft and 13.49 ft were observed for the No Policy group and the Policy group, respectively).
Table 3: Summary of lateral overtaking distances and speed by scenario and experimental group

<table>
<thead>
<tr>
<th>Traffic Scenario</th>
<th>Variables</th>
<th>No Policy Group</th>
<th></th>
<th>Policy Group</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lateral Distance (ft)</td>
<td>Speed (mph)</td>
<td>Lateral Distance (ft)</td>
<td>Speed (mph)</td>
<td>Lateral Distance (ft)</td>
<td>Speed (mph)</td>
</tr>
<tr>
<td>Low</td>
<td>No. Observations</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>5.98</td>
<td>32.13</td>
<td>6.18</td>
<td>31.53</td>
<td>6.08</td>
<td>31.83</td>
</tr>
<tr>
<td></td>
<td>(Standard Deviation)</td>
<td>(2.26)</td>
<td>(9.32)</td>
<td>(2.40)</td>
<td>(6.49)</td>
<td>(2.30)</td>
<td>(7.93)</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>3.21</td>
<td>19.19</td>
<td>2.11</td>
<td>25.13</td>
<td>2.11</td>
<td>19.19</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>10.959</td>
<td>61.12</td>
<td>11.01</td>
<td>50.67</td>
<td>11.01</td>
<td>61.12</td>
</tr>
<tr>
<td></td>
<td>No. Non-compliant (%)</td>
<td>0 (0)</td>
<td>-</td>
<td>1 (5)</td>
<td>-</td>
<td>1 (2.5)</td>
<td>-</td>
</tr>
<tr>
<td>Medium</td>
<td>No. Observations</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>5.73</td>
<td>29.12</td>
<td>6.18</td>
<td>31.05</td>
<td>5.96</td>
<td>30.09</td>
</tr>
<tr>
<td></td>
<td>(Standard Deviation)</td>
<td>(2.11)</td>
<td>(4.42)</td>
<td>(2.77)</td>
<td>(5.78)</td>
<td>(2.44)</td>
<td>(5.17)</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>2.73</td>
<td>22.56</td>
<td>2.04</td>
<td>21.9</td>
<td>2.04</td>
<td>22.56</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>9.97</td>
<td>36.7</td>
<td>13.49</td>
<td>42.81</td>
<td>13.49</td>
<td>42.81</td>
</tr>
<tr>
<td></td>
<td>No. Non-compliant (%)</td>
<td>2 (10)</td>
<td>-</td>
<td>1 (5)</td>
<td>-</td>
<td>3 (7.5)</td>
<td>-</td>
</tr>
<tr>
<td>High</td>
<td>No. Observations</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
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<td></td>
<td>Mean</td>
<td>6</td>
<td>29.4</td>
<td>6.28</td>
<td>30.80</td>
<td>6.14</td>
<td>30.10</td>
</tr>
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<td>(Standard Deviation)</td>
<td>(2.98)</td>
<td>(5.86)</td>
<td>(2.91)</td>
<td>(5.13)</td>
<td>(2.91)</td>
<td>(5.48)</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>2.48</td>
<td>21.16</td>
<td>1.22</td>
<td>22.03</td>
<td>1.22</td>
<td>21.16</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>11.54</td>
<td>42.25</td>
<td>11.35</td>
<td>40.29</td>
<td>11.54</td>
<td>42.25</td>
</tr>
<tr>
<td></td>
<td>No. Non-compliant (%)</td>
<td>3 (15)</td>
<td>-</td>
<td>1 (5)</td>
<td>-</td>
<td>4 (10)</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>No. Observations</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>5.90</td>
<td>30.22</td>
<td>6.21</td>
<td>31.13</td>
<td>6.059</td>
<td>30.67</td>
</tr>
<tr>
<td></td>
<td>(Standard Deviation)</td>
<td>(2.44)</td>
<td>(6.87)</td>
<td>(2.65)</td>
<td>(5.73)</td>
<td>(2.54)</td>
<td>(6.32)</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>2.48</td>
<td>19.19</td>
<td>1.22</td>
<td>21.9</td>
<td>1.22</td>
<td>19.19</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>11.54</td>
<td>61.12</td>
<td>13.49</td>
<td>40.29</td>
<td>13.49</td>
<td>61.12</td>
</tr>
<tr>
<td></td>
<td>No. Non-compliant (%)</td>
<td>5 (8.3)</td>
<td>-</td>
<td>3 (5)</td>
<td>-</td>
<td>8 (6.7)</td>
<td>-</td>
</tr>
</tbody>
</table>
On average, participants on both groups provided more than the three feet minimum distance required. The highest average overtaking distance was observed for participants in the Policy group (6.21ft) when compared to the No Policy group (5.90ft). However, this difference of 3.72 inches was not found to be significant (F= 0.429, p=0.5139). The results, therefore, suggest that the “three-foot” law, by itself, did not have an effect on the mean lateral overtaking distance collected under the conditions considered in this study.

4.1.2 Overtaking Speed

Overall, observed overtaking speeds were between the range of 19.29 mph - 61.12 mph for the No Policy group and 21.90 mph – 40.29 mph for the Policy group. On average, overtaking speeds were observed to be higher in the Policy group (31.13 mph) when compared to the No Policy (30.22 mph). However, this difference of approximately 1 mph was not found to be significant (F=0.613, p=0.435). The results, therefore, suggest that the awareness of the three-foot passing law did not have an effect on the mean overtaking speeds collected under the conditions considered in this study.

4.2 Effect of Opposing Traffic Streams

Regarding the effect of varying opposing traffic conditions on the overtaking behavior of the subject participants, it was hypothesized that:

1- Varying opposing traffic volume conditions have an effect on the average lateral overtaking distances that participants provide.

2- Varying opposing traffic volume conditions have an effect on the average overtaking speeds of the participants.
To test these hypotheses, a two-way analysis of variance (ANOVA) was performed at a five percent level of significance (α=0.05) and the results are presented in the following subsections.

4.2.1 Lateral Overtaking Distance

Overall, violations of the minimum three-foot lateral separation requirement were observed for the low (2.11 ft), medium (2.04 ft), and high (1.22 ft) traffic scenarios. Lateral distances provided reach over 8 to 11 feet more separation than the minimum requirement (11.01 ft for the “low traffic” scenario, 13.49 for the “medium traffic” scenario, and 11.54 ft for the “high traffic” scenario). On average, participants provided more than the minimum distance required. The average overtaking distances observed were 6.08 ft, 5.96 ft, and 6.14 ft for the low, medium, and high traffic volume conditions, respectively. The differences between average overtaking distances among scenarios were not significant (F=0.052, p=0.949). The results, therefore, suggest that traffic volume conditions on the on-coming lane, by itself, did not have an effect on the mean lateral overtaking distances and speeds collected under the conditions considered in this study. The results observed likely occurred due to factors noticed during the experiment. For instance, at least 50 percent of the test subjects waited until all opposing traffic had ceased before overtaking. This shows that participants were willing to wait until they found a larger gap. Bias results are therefore likely to have occurred in the medium and high volume scenarios resulting in these groups having no significant difference to the low volume scenario.
4.2.2 Overtaking Speed

In the low traffic volume condition overtaking speeds were observed between 19.19 mph and 61.12 mph, 22.56 mph and 42.81 mph for the medium traffic volume, and 21.16 mph and 42.25 mph for the high traffic volume condition. On average, the highest overtaking speed observed was in the low volume traffic scenario (31.83 mph). Mean overtaking speeds of 30.10 mph and 30.09 mph were observed for the high and medium traffic scenario, respectively. However, the differences between average overtaking distances among scenarios were not significant (F=0.994, p=0.373).

4.3 Combined Effect of the Law and Opposing Traffic Streams

An assessment of a three-foot passing law on the overtaking behavior of study participants was conducted by investigating the effect of the law in the presence of varying opposing traffic streams. It was hypothesized that:

1- Knowledge of the law in the presence of varying opposing traffic volume conditions has an effect on the average lateral overtaking distances provided by the participants.

2- Knowledge of the law in the presence of varying opposing traffic volume conditions has an effect on the average overtaking speeds of the participants.

4.3.1 Lateral Overtaking Distance

When evaluating the combined effect of the three-foot laws in the presence of opposing traffic conditions, the results indicate that mean lateral distances at the time of overtaking were not significantly different (F= 0.0259, p= 0.974). This suggests that lateral overtaking distance
provided by participants who were fully aware of the three-foot law did not vary significantly from those who were unaware among all three traffic volume conditions.

4.3.2 Overtaking Speed

When evaluating the combined effect of the three-foot laws in the presence of opposing traffic conditions, the results indicate that mean speeds at the time of overtaking were not significantly different with F= 0.440, p= 0.645. This suggests that lateral overtaking distance provided by participants who were fully aware of the three-foot law did not vary significantly from those who were unaware in all three traffic volume conditions.

4.4 Perceived Mean and Actual Mean Lateral Overtaking Distance

In the exit questionnaire, participants were inquired about the average number of feet they felt provided when overtaking the three male bicyclists in the simulation. It was hypothesized that drivers have difficulty estimating the average distance they provided when overtaking. To investigate this, a paired t-test was conducted at the five percent level of significance (α=0.05). Table 4 presents the results of the analysis. It can be seen that there is not a significant difference between the observed and the perceived mean lateral overtaking distances reported (p= 0.416). Thus this suggests that participants were able to approximate the average distance they provided during the simulation.
### Table 4: Results of the Paired Two Sample for Means

<table>
<thead>
<tr>
<th>Variables</th>
<th>Recorded mean distance (ft)</th>
<th>Perceived mean distance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>6.05877505</td>
<td>5.39375</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.34628888</td>
<td>27.4772035</td>
</tr>
<tr>
<td>No. Observations</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.27481915</td>
<td>-</td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.41643519</td>
<td>-</td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>2.02269092</td>
<td>-</td>
</tr>
</tbody>
</table>

### 4.5 Awareness of the Law Prior to the Experiment (Policy group)

Participants were inquired if they knew about the three-foot passing law prior to receiving instructions about the experiment. Seventy percent of the participants in the Policy group reported that they were not aware of the three-foot passing laws prior to being informed by the investigator (see Figure 9).

### 4.6 Perceived Obstacles to Overtaking

Participants were asked to select and indicate factors that, in their opinion, made it difficult to overtake the bicyclists in the simulation. This question was intended to identify the factors that drivers perceived had an effect on their behavior.
Figure 9: Distribution of participants by familiarity with the laws

Figure 10 and 11 show the factors indicated by participants in the No Policy and the Policy group, respectively. It can be seen that in each group opposing traffic was perceived as the major obstacle followed by the combination of opposing traffic and bicyclist’s riding position. Figure 12 shows the perception of all subject participants. Once again, the overall perception is that opposing traffic makes overtaking maneuvers more difficult.
Figure 10: Perceived Obstacles to Overtaking (No Policy Group)
Figure 11: Perceived Obstacles to Overtaking (Policy Group)
4.7 Behavior of “Drivers Only” and “Drivers and Bicyclists”

Participants were asked if they frequently bike. Those who answered yes fell in the category of “Drivers and Bicyclists” while those who answered no were classified as “Drivers Only”.

Figure 13 shows the distribution of bicyclists among all participants and by experimental group. Overall, it can be seen that 82.5 percent of all participants were “Drivers Only.” In the No Policy group, 95 percent of the participants did not bike frequently. On the other hand, 70 percent of participants in the Policy group did not bike frequently.
Figure 13: Distribution of “Drivers Only” and “Drivers and Bicyclists”

Table 5 summarizes the results obtained from the statistical analyses described in this Chapter. The shaded areas show the conditions that were found to be significant.

Table 5: Results of Statistical Analyses Performed

<table>
<thead>
<tr>
<th>Condition</th>
<th>Lateral Distance (ft)</th>
<th>Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy awareness</td>
<td>F=0.429, p=0.5139 (non-significant)</td>
<td>F=0.613, p=0.435 (non-significant)</td>
</tr>
<tr>
<td>Opposing traffic volume conditions</td>
<td>F=0.052, p=0.949 (non-significant)</td>
<td>F=0.994, p=0.373 (non-significant)</td>
</tr>
<tr>
<td>Interaction effect</td>
<td>F=0.0259, p=0.974 (non-significant)</td>
<td>F=0.440, p=0.645 (non-significant)</td>
</tr>
</tbody>
</table>
CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Despite the expectation for improved safety, no research has been conducted to assess how well drivers understand and drive in response to the three-foot bicycle passing laws. Therefore, an assessment of these laws on the overtaking behavior of study participants was conducted by investigating the effect of the law by itself and in the presence of varying opposing traffic streams (i.e. low, medium, and high). The effect of varying opposing traffic conditions, by itself, was also explored and quantified.

Overall, 120 overtaking events from 40 volunteered participants were processed and analyzed. In general, the results of the research showed that the behavior of study participants who were informed about the three-foot passing law was no different from that of participants unaware of the law. This was illustrated when comparing the average distances at the time of overtaking observed for participants in the No Policy group (5.90 ft) and in the Policy group (6.21 ft). Additionally, no statistically significant difference was found when comparing the speeds of participants in the No policy group (30.2 mph) and the Policy group (31.1 mph). These findings were unexpected and contradictory to the intent of the law that it will change driver behavior. Although the average tendency of participants in each group was to provide more than three feet, 8 percent of the No Policy and 5 percent of the Policy group, provided less than three feet of lateral distance. Since these violations were small, this suggest that the natural tendency of the participants was to provide more than the three-foot minimum requirement whether they were aware about the law or not. This tendency was also expected and consistent from prior research conducted in rural roadways (25, 38). For example, the study of Chapman and Noyce (2014) reported an average overtaking distance of 6.3 ft.
The available gaps provided by the opposing traffic streams modelled in the study did not have a significant effect on the average overtaking distances and speeds observed. This was illustrated when comparing the observations of both experimental groups (Policy and No Policy) in the presence of various traffic volume scenarios (low, medium, and high) in which no significant effects were found in the mean lateral overtaking distances and speeds. This suggests that participants tended to provide the distance they felt comfortable regardless of opposing traffic conditions and prior knowledge of the law. These results were inconsistent with previous studies conducted in rural and urban roadways where the presence of opposing traffic was found to be a significant factor on lateral distances at the time of overtaking (24, 25). However, Llorca et al. (2015) collected data in rural roads in Spain and found not significant effect (15). The observation from this study likely resulted from factors noticed during the experiment. For instance, at least fifty percent of the test subjects waited until all opposing traffic had ceased before overtaking. Bias results are therefore likely to have occurred in the medium and high volume scenarios resulting in these groups having no significant difference to the low volume scenario. However, from these observations one can conclude that most participants were willing to wait until they found a larger gap.

The study also investigated the ability of drivers to estimate the lateral distances provided when overtaking the bicyclists in the simulation. This was investigated by comparing the perceived average lateral overtaking distance provided and the actual average measurements. The results showed that it was not an issue for the study participants. This observation suggests that stating a minimum distance requirement in the law can be interpreted and understood.

Based on the findings of this research, contributions to knowledge from practical and theoretical perspectives were identified. In a practical perspective, this approach can complement
prior methods of assessment because more variables can be controlled to evaluate the effects of variables that result dangerous in field-based naturalistic experiments. An example of this is the assessment of the behavior of impaired drivers, and the study of high speed corridors. From a theoretical perspective, the small number of violations of the law in this study and in previous studies may suggest that drivers were naturally mindful of the bicyclists under the conditions studied. External conditions such as road lighting/visibility may be a more critical factor that is leading to drivers colliding with bicycles, like Cross and Fisher (1975) described. Having the law, however, may serve as a legal framework to cite drivers when passing too close. The human component of driver behavior is also key in enhancing safety. These laws seem to be sensible and reasonable enough for drives, therefore, enforcement in combination with education is a necessary step to ensure the law is not violated under several conditions.

From an application viewpoint, it is expected that the results presented here can also be adapted and used as basis for future studies and comparison of other models. Future research will be able to build upon this work by having a larger participant pool and modelling higher vehicular flow. Another area of particular interest is to explore driver behavior by varying elements of the tested environments (e.g. lane width, visibility conditions, time of the day, bicyclist path, overtaking vehicle type).
REFERENCES


APPENDIX A: CONSENT FORM

Informed Consent Form

Study Title: Driving simulator study to assess transportation policies on driver behavior

Performance Site: Louisiana State University and Agricultural and Mechanical College, Room 2225 Patrick F. Taylor Hall.

Investigators: The following investigators are available for questions about this study,

M-F, 8:30 AM – 4:30 PM, Dr. Brian Wolshon, brian@rsip.lsu.edu, (225)578-5247
M– F, 8:00 AM–5:00 PM: Nélida Herrera, nherre2@lsu.edu, (225)290-8129,

Purpose of the study: This study assesses transportation policies on driver behavior

Subject Inclusion: Individuals between the ages of 18 and 65 with normal or corrected to normal vision and possess a valid driver’s license and who are not prone to motion sickness.

Subject Exclusion: Pregnant women are excluded from participating in this study

Number of subjects: 100

Study Procedure: The experiment consists of four stages. First, participants will be asked to fill out a profile questionnaire which takes about one minute to complete. Then, participants will start a pre-run in which they will be asked to drive the driving simulator until they familiarize themselves with the simulator’s controls. In the following stage, participants will be asked to drive the LSU driving simulator as they would normally drive their own car. The test trial takes no more than seven minutes to complete. Finally, participants will answer questions related to their driver experience during the simulation. This takes about one minute. The experiment should take between 10 minutes to 15 minutes.

Benefit: Findings from this experiment may assist policy-makers in developing new safety strategies or improving current strategies to reduce collisions.

Risks/Discomforts: All research has some degree of risks associated. In the case of driving simulators, certain effects known as simulator sickness may occur. These are similar to motion sickness or air sickness in a plane. The symptoms include: drowsiness, dizziness, nausea, eyestrain, headache, disorientation, vertigo, sweating and postural instability. If you have a predisposition towards motion sickness of any kind, please inform any of the investigators immediately. If you present any of these conditions during the experiment, please let the investigator know and press the emergency safe knob at any time. This will stop the simulation. If you use the emergency safe knob, you will NOT be penalized or lose any benefit you would otherwise have received. Therefore, you are encouraged to use it as you feel the slightest discomfort.
**Right to refuse:** Participants voluntarily choose to participate and they may withdraw from the experiment at any time without penalty or loss of any benefit to which they might otherwise be entitled.

**Privacy:** This study is confidential and no names will be collected. Any results that may be published will not have any identifying information linked to it.

**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 subjects’ rights or other concerns, I can contact Dennis Landin, Chairman, LSU Institutional Review Board, (225)578-8692, irb@lsu.edu, www lsu.edu/irb. I agree to participate in the study described above and acknowledge the researchers’ obligation to provide me with a copy of this consent form if signed by me.

Subject Signature: ___________________________ Date: ____________
APPENDIX B: IRB ACTION PROTOCOL APPROVAL REQUEST

ACTION ON PROTOCOL APPROVAL REQUEST

TO: Brian Wolshon
Civil Engineering

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: July 2, 2015

RE: IRB# 3622

TITLE: Driving simulator study to assess transportation policies on driver behavior


Review type: Full ___ Expedited ___ X ____ Review date: 7/2/2015

Risk Factor: Minimal ___ X ___ Uncertain ______ Greater Than Minimal_______

Approved ___ X ___ Disapproved_______

Approval Date: 7/2/2015 Approval Expiration Date: 7/1/2016

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 100

LSU Proposal Number (if applicable):

Protocol Matches Scope of Work in Grant proposal: (if applicable) ________

By: Dennis Landin, Chairman

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING – Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of all changes in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
8. SPECIAL NOTE:

*All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb

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APPENDIX C: ENTRY QUESTIONNAIRE

Participant ID

Participant Profile Questionnaire

Please answer the questions below.

1. What is your gender?
   - [ ] Male
   - [ ] Female

2. What is your age? ________

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

4. What type of vehicle do you drive?
   - [ ] Pick-up truck
   - [ ] SUV
   - [ ] Van
   - [ ] Sedan
Exit Questionnaire

1. In average, how many feet do you think you left between your car and the bicyclist when overtaking/passing the bicyclist? ____________

2. Were you familiar with the three-foot bicycle passing law, prior to today?
   - [ ] Yes
   - [ ] No

3. If yes, did you apply the law when overtaking?
   - [ ] Yes
   - [ ] No

4. If no, do you think you would have given the bicyclists more space had you known about the law?
   - [ ] Yes
   - [ ] No

5. What do you think makes it difficult to pass a bicycle?
   - [ ] Presence of opposing traffic
   - [ ] Position of the bicyclists on the road
   - [ ] Speed of the bicyclist
   - [ ] Other, specify ____________________________

6. Do you frequently bike?
   - [ ] Yes
   - [ ] No
VITA

Nelida A. Herrera, daughter of Alfredo and Nelida, was born in Baruta, Venezuela, in November 1990. Nelida has two older siblings, Carolina and Alfredo. Nelida arrived to the United States in 2010 to learn English as a Second Language at the English Language and Orientation Program. After four months, Nelida started her undergraduate studies in the Civil and Environmental Program at Louisiana State University in August 2010. During her undergraduate studies, she interned at Fenstermaker and ARCADIS. Nelida graduated Summa Cum Laude as a Bachelor of Science in civil engineering in May 2014. She then started her graduate studies at Louisiana State University in August 2014. Nelida entered the Master’s program as a research assistant for Dr. Brian Wolshon and she is now a candidate for the degree of Master of Science from The Department of Civil and Environmental Engineering at Louisiana State University.