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The Use Of The Ucf Driving Simiulator To Test The Contribution Of Larger Size Vehicles (lsvs) In Rear-end Collisions And Red Light Running On Intersections.

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THE USE OF THE UCF DRIVING SIMIULATOR TO TEST THE CONTRIBUTION OF LARGER SIZE VEHICLES (LSVs) IN REAR-END COLLISIONS AND RED LIGHT RUNNING ON INTERSECTIONS.

By

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ABSTRACT

Driving safety has been an issue of great concern in the United States throughout the years. According to the National Center for Statistics and Analysis (NCSA), in 2003 alone, there were 6,267,000 crashes in the U.S. from which 1,915,000 were injury crashes, including 38,764 fatal crashes and 43,220 human casualties. The U.S. Department of Transportation spends millions of dollars every year on research that aims to improve roadway safety and decrease the number of traffic collisions. In spring 2002, the Center for Advanced Traffic System Simulation (CATSS), at the University of Central Florida, acquired a sophisticated reconfigurable driving simulator. This simulator, which consists of a late model truck cab, or passenger vehicle cab, mounted on a motion base capable of operation with six degrees of freedom, is a great tool for traffic studies.

Two applications of the simulator are to study the contribution of Light Truck Vehicles (LTVs) to potential rear-end collisions, the most common type of crashes, which account for about a third of the U.S. traffic crashes, and the involvement of Larger Size Vehicles (LSVs) in red light running. LTVs can obstruct horizontal visibility for the following car driver and has been a major issue, especially at unsignalized intersections. The sudden stop of an LTV, in the shadow of the blindness of the succeeding car driver, may deprive the following vehicle of a sufficient response time, leading to high probability of a rear-end collision. As for LSVs, they can obstruct the vertical visibility of the traffic light for the succeeding car driver on signalized intersection producing a potential red light running for the latter.

Two sub-scenarios were developed in the UCF driving simulator for each the vertical and horizontal visibility blockage scenarios. The first sub-scenario is the base sub-scenario for both scenarios, where the simulator car follows a passenger car, and the second sub-scenario is the test sub-scenario, where the simulator car follows an LTV for the horizontal visibility blockage scenario and an LSV for the vertical visibility blockage scenario.

A suggested solution for the vertical visibility blockage of the traffic light problem that consisted of adding a traffic signal pole on the right side of the road was also designed in the driving simulator.

The results showed that LTVs produce more rear-end collisions at unsignalized intersections due to the horizontal visibility blockage and following car drivers' behavior. The results also showed that LSVs contribute significantly to red light running on signalized intersections and that the addition of a traffic signal pole on the right side of the road reduces the red light running probability.

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CHAPTER 1: INTRODUCTION

1.1 Problem statement

Vertical and horizontal visibility blockages are real life problems causing violations of traffic laws like red light running and creating an environment conducive to traffic crashes. Horizontal view blockage occurs when a driver's visibility is inhibited to his left or/and right at an intersection. This can occur when someone is driving a passenger car, which could be any Sedan type car such as Saturn, Honda Accord, Nissan Sentra, or Ford Taurus, closely behind a Light Truck Vehicle (LTV), such as vans and SUVs. In fact, LTVs obstruct horizontal view because they ride higher and wider than the passenger car. Therefore, the passenger car driver won't be able to see and know what is happening beyond the LTV at the intersection. For example, when a pedestrian invisible to a passenger car driver following an LTV suddenly crosses the intersection from left to right, the LTV driver is forced to slam on his brakes leaving the succeeding passenger car driver with almost no time to react appropriately and stop, which could lead to a collision with the LTV.

Vertical view blockage occurs when traffic light visibility is inhibited. For example, if someone is driving a passenger car closely behind a larger size vehicle (LSV) such as large trucks semis or buses, through a signalized intersection, the traffic light will not be visible until the driver is almost directly under it. Therefore, the driver won't be aware of any traffic signal change until it is too late, which could lead to red light running.

1.2 Research Objectives

The main objectives of this research are:

(1) To determine whether driving behind an LTV increases the probability of rear-end collisions due to horizontal view blockage.

(2) To verify if driving behind an LSV contributes to red light running due to vertical view blockage at signalized intersections.

(3) To assess the effect of adding an additional traffic signal pole on the side of the road on solving vertical visibility problems.

(4) To evaluate drivers' behavior model at intersections, including speeds and gaps when driving behind LTV and LSV.

(5) To analyze the parameters that resulted in higher accident rates including decelerations, accelerations, and response delay times.

1.3 Background

1.3.1 Horizontal view blockage related literature review

According to the National Center for Statistics and Analysis (NCSA), in 2003 alone, there were 6,267,000 crashes in the U.S. from which 1,915,000 were injury crashes, including

38,764 fatal crashes and 43,220 human casualties. Wang et al. (1999) stated that the most abundant crash category is rear-ending collisions. Rear-end collisions are the most common forms of traffic crashes in the U.S. accounting for nearly third of the 6 million crashes reported annually nationwide. In the past two years, the National Transportation Safety Board investigated nine rear-end collisions in which 20 people died and 181were injured. Common to all nine crashes was the rear following vehicle drivers' degraded perception of traffic conditions ahead.

One of the main reasons of rear-end collisions relies on the abundance of the Light Truck Vehicles (LTVs) on the U.S. highways nowadays. For year 2000, Motor vehicle registrations show 77.8 million light trucks in the U.S., a 63.8% increase from 1990. During the same period, there was 1% decrease in the number of passenger cars (PCs). LTVs now present 40% of all registered vehicles.

The LTVs include light-duty trucks, vans, and sport utility vehicles (SUVs). The high number of accidents related to the abundance of LTVs might be the result of the geometric incompatibility arising from the fact that most LTVs ride higher and wider than regular passenger cars. Abdel-Aty and Abdel Wahab (2003) presented an analysis of the geometric incompatibility of LTVs on driver's visibility of other passenger cars involved in rear-end collisions with the objective to explore the effect of the lead vehicle's size on the rear-end crash configuration. Results of the calibrated nested logit model suggested that LTV blocks drivers' visibility if the other passenger cars.

Sayer et al. (2000) examined the effect that the lead vehicle sizes such as height and width has on a passenger car driver's gap maintenance under near optimal driving conditions characterized by daytime, dry weather, and free-flowing traffic. The data were obtained from a random sample of licensed drivers who drove an instrumented passenger car, unaccompanied, as their personal vehicle 2-5 weeks. Results showed that passenger car drivers followed LTV at shorter distance than they followed passenger cars, but at the same velocities. Also, the results of this study suggested that knowing the state of the traffic behind the lead vehicle, even by only one additional vehicle, affects gap length. Specifically, it appears that when dimensions of lead vehicles permit following drivers to see through, over, and around them, drivers maintain significantly longer distances. Acierno (2004) related the mismatch in weight, stiffness, and height between LTV and PC to the increase in fatalities among Passenger car occupants when their vehicle collides with LTV. Cases of vehicle mismatch collisions were studied in the Seattle Crash Injury research and Engineering Network (CIREN) database to establish patterns and source of injury. Of the first 200 Seattle CIREN cases reviewed, 32 collisions with 41 occupant cases were found to involve LTV versus PV. In conclusion, Acierno associated vehicle mismatch with death and serious injury in automotive crashes an also recommended design improvement to both PV and LTV.

Aty and Abdel Wahab (2004) investigated the effect of the increasing number of LTV registration on fatal angle collisions trends on the U.S. The analysis investigates the number of annual fatalities that result from angle collisions configuration (car-car, car-LTV, LTV-car, LTV-LTV). The analysis uses the Fatality Analysis Reporting System

(FARS) crash databases covering the period 1975-2000. Results showed the death rates differ based on the collision configuration. Forecast showed that the total number of annual deaths is expected to reach 6300 deaths by year 2010 (an increase of 12% over 2000). Modeling results showed that the coefficient of LTV percentage in the system of regression equations was significant because of the instantaneous effect (time lag equals to 0) of LTVs on the annual fatalities resulting from angle collisions.

1.3.2 Vertical view blockage related literature review

Red-light running contributes to substantial numbers of motor vehicle crashes and injuries on a national basis. Retting et al reported that drivers who run red-lights were involved in an estimated 260,000 crashes each year, of which approximately 750 are fatal, and the number of fatal motor vehicle crashes at traffic signals increased 18% between 1992 and 1998, far outpacing the 5% rise in all other fatal crashes (Retting et al., 2002). Motorists are more likely to be injured in crashes involving red-light running than in other types of crashes, according to analyses of police-reported crashes from four urban communities; occupant injuries occurred in 45% of the red-light running crashes studied, compared with 30% for all other crashes in the same communities.

In Texas, a report showed that the number of people killed or injured in red-light running crashes had increased substantially over the years. The increase (79 percent from 1975 to 1999) is similar to the increase in the number of people killed or injured in motor vehicle crashes in general, and is also similar to the increase in vehicle miles traveled in the state.

About 16 percent of people killed in intersection crashes and 19–22 percent of people injured in intersection crashes are involved in red-light running (Quiroga et al., 2003).

According to the Federal Highway Administration (FHWA), the following traffic facts about red-light running were posted in its main website:

- Each year, more than 1.8 million intersection crashes occur.
- In 2000, there were 106,000 red-light running crashes that resulted in 89,000 injuries and 1,036 deaths.
- Preliminary estimates for 2001 indicate 200,000 crashes, 150,000 injuries, and about 1,100 deaths were attributed to red-light running.
- Overall, 55.8 percent of Americans admit to running red lights. Yet ninety-six percent of drivers fear they will get hit by a red-light runner when they enter an intersection.

Red-light running is a highly dangerous driving act and also it is the most frequent type of police-reported urban crash. A study provided 5,112 observations of drivers entering six traffic-controlled intersections in three cities. Overall, 35.2% of observed light cycles had at least one red-light runner prior to the onset of opposing traffic. This rate represented approximately 10 violators per observation hour (Porter and England, 2000). Another study conducted over several months at a busy intersection (30,000 vehicles per day) in Arlington, VA revealed violation rates of one red-light runner every 12 min. and during the morning peak hour, a higher rate of one violation every 5 min. A lower volume intersection

(14,000 vehicles per day), also in Arlington, had an average of 1.3 violations per hour and 3.4 in the evening peak hour (Retting et al., 1998).

Thus, based on both previous research and accident data, red-light running crashes represent a significant safety problem that warrants attention.

Retting at al. (1999) analyzed drivers' characteristics involving fatal red-light running accidents using 1992–1996 data from the FARS and GES databases. For the analysis, they only considered fatal crashes for which one driver had committed a red-light running violation and both drivers were going straight prior to the crash. The following were the main findings of the study:

- Some 57 percent of fatal red-light running crashes occurred during the day. By comparison, 48 percent of other fatal crashes occurred during the day. However, fatal red-light running crashes that involved drivers less than 70 years old peaked around midnight, whereas fatal red-light running crashes that involved drivers 70 years old or older occurred primarily during the day.
- On average, 74 percent of red-light runners and 70 percent of non-runners were male. Of all nighttime red-light runners, 83 percent were male. Of all daytime red-light runners, 67 percent were male. It may be worth noting that male drivers accounted for roughly 61 percent of the vehicle miles traveled on U.S. roads, according to results from the 1995 Nationwide Personal Transportation Survey .
- Some 43 percent of red-light runners were younger than age 30. By comparison, 32 percent of non-runners were younger than age 30.

- Red-light runners were much more likely to drive with suspended, revoked, or otherwise invalid driver licenses. Younger drivers were more likely to be unlicensed.

From the perspective of crash types of red-light running, while most red-light running crashes involve at least two vehicles, crashes involving a single vehicle and an alternative transportation mode (pedestrian or bicyclist) can occur. A single vehicle, hit fixed object crash could occur when either the running-the-red violator or the opposing legal driver takes evasive action to avoid the other and crashes into an object, e.g. a signal pole. Also, a running-the-red violator can hit a pedestrian or bicyclist who is legally in the intersection.

A comprehensive report (FHWA, 2003) on red-light running issue concluded that the following crash types could be possible target crashes for a red-light study: Right-angle (side impact) crashes, Left turn (two vehicles turning), Left turn (one vehicle oncoming), Rear end (straight ahead), Rear end (while turning), and other crashes specifically identified as red-light running.

The FHWA report also pointed out that researchers reviewed the police reports of 306 crashes that occurred at 31 signalized intersections located in three states. Traffic-signal violation was established as a contributing factor and the reason for the violation was provided in 139 of the crashes. The distribution of the reported predominant causes is as follows:

- 40 percent did not see the signal or its indication;
- 25 percent tried to beat the yellow-signal indication;

- 12 percent mistook the signal indication and reported they had a green-signal indication;
- 8 percent intentionally violated the signal;
- 6 percent were unable to bring their vehicle to a stop in time due to vehicle defects or environmental conditions;
- 4 percent followed another vehicle into the intersection and did not look at the signal indication;
- 3 percent were confused by another signal at the intersection or at a closely spaced intersection; and
- 2 percent were varied in their cause.

From the above results, 44% of the crashes were attributed to view blockage of the traffic light. The above research results show that red-light running is a complex problem. There is no simple or single reason to explain why drivers run red lights. However, they can be classified into two types, intersection factors and human factors.

Another study's objective was to examine selected intersection factors and their impact on RLR crash rates and to establish a relationship between them. The results obtained from the model show that the traffic volume on both the entering and crossing streets, the type of signal in operation at the intersection, and the width of the cross-street at the intersection are the major variables affecting red-light running crashes (Mohamedshah, 2000). The FHWA report summed that, among intersection factors are intersection flow rates, frequency of signal cycles, vehicle speed, travel time to the stop line, type of signal control, duration of the yellow interval, approach grade, and signal visibility (FHWA, 2003).

How intersection factors and human factors interact to increase or decrease the risk of red-light running varies considerably from intersection to intersection. Those factors point to the need to implement engineering countermeasures to improve traffic flow, improve visibility, help drivers make driving maneuvers and reduce conflicts. Other factors, especially related to deliberate illegal driving behaviors, point to the need to also implement strategies such as improved enforcement and public awareness.

Bonneson (2001) also discussed the factors that affect the driver's decision to stop or proceed through the intersection upon seeing the onset of the yellow. There are three main components of the decision process: driver behavior (expectancy and knowledge of operation of the intersection), estimated consequences of not stopping and estimated consequences of stopping. What if the driver makes his decision to proceed through the intersection based on the factors above, but ends up running the red light? Bonneson divides red-light runners into two categories. The first is the intentional violator who, based on his/her judgment, knows they will violate the signal, yet he/she proceeds through the intersection. This type of driver is often frustrated due to long signal delays and perceives little risk by proceeding through the intersection. The second type of driver is the unintentional driver who is incapable of stopping or who has been inattentive while approaching the intersection. This may occur as a result of poor judgment by the driver or a deficiency in the design of the intersection. Bonneson further indicates that intentional red-light runners are most affected by enforcement countermeasures while unintentional red-light runners are most affected by engineering countermeasures.

According to characteristics and reasons of red-light running, traffic engineers are trying to develop a number of methods to reduce the red-light running rate. Currently, engineering countermeasures include signal operation countermeasures (e.g., increasing the yellow interval duration, providing green extension, improving signal coordination, and improving signal phasing), motorist information countermeasures (e.g., improving sight distance, improving signal visibility and conspicuity, and adding advance warning signs), and physical improvement countermeasures (e.g., removing unneeded signals, adding capacity with additional traffic lanes, and flattening sharp curves). Signal operation countermeasures can effectively reduce the incidence of red-light running by improving traffic flow characteristics and by reducing the exposure of individual vehicles to situations that might result in red-light running. Motorist information countermeasures that focus on attracting the attention of drivers to the signal can effectively reduce the incidence of red-light running.

In recent years, a lot of researches are related to evaluation on effects of red-light camera implementation. In one side, the review of the effectiveness of those systems reveals that red-light cameras are effective deterrence tools and have a positive safety impact; even where the implementation of engineering countermeasures had not preceded the installation and operation of cameras. On the other side, the review also shows that red-light cameras can contribute to an increase in the number of rear-end crashes; however, this effect is relatively small and temporary and camera presence (or the presence of warning signs) had no significant effect on red-running behavior (Quiroga et al., 2003). Furthermore, some report (The Red-light Running Crisis: Is it Intentional, 2001) questions whether motorists identified in Institute studies as red-light violators are, in fact, innocent drivers who were unable to stop in time to comply with the signals. The fact is that red-light cameras are designed to identify only deliberate violators, those who enter intersections well after the end of a yellow signal phase.

To help drivers make their decision at the onset of yellow, some motorist information countermeasures are implemented by enhancing the signal display or by providing advance information to the driver about the signal ahead. With the additional information, the probability that a driver will stop for a red signal may increase. Among them, the two most prevailing and controversial countermeasures are pre-yellow signal indication and advance warning signs.

Advance warning signs forewarn drivers that they are approaching a signalized intersection. Figure 2-1 shows two types of warning signs. Figure 2-1a shows a sign that uses a "signal ahead" symbolic message. Flashing beacons sometimes accompany this sign to ensure drivers detect and interpret the sign's meaning. Figure 2-1b shows a "Be Prepared to Stop When Flashing" sign. This sign has the beacons flashing only during the last few seconds of green. It is sometimes referred to as an "advance warning sign with active flashers." In this mode, the flashing indicates when the signal indication is about to change from green to yellow. When flashing beacons accompany these advance warning signs, they are also named advance warning flashers (AWF). The purpose of AWF is to forewarn the driver when a traffic signal on his/her approach is about to change to the yellow and then the red phase. An effective AWF implementation is intended to minimize the number of vehicles in the dilemma zone during the change interval. In North America, there are three general types of advanced warning devices and the decision of which to use is based on engineering judgment. These AWFs include:

- Prepare to stop when flashing (PTSWF)—A warning sign, BE PREPARED TO STOP with two yellow flashers that begins to flash a few seconds before the onset of the yellow and continue to flash throughout the red phase. A WHEN FLASHING plaque is recommended in addition to the sign.
- Flashing symbolic signal ahead (FSSA)—Similar to previous type except the wording on the sign is replaced by a schematic of a traffic signal. The flashers operate as above.
- Continuous flashing symbolic signal ahead (CFSSA)—The sign displays a schematic of a traffic-signal symbol but in this case, the flashers operate continuously (i.e. they are not connected to the signal controller).

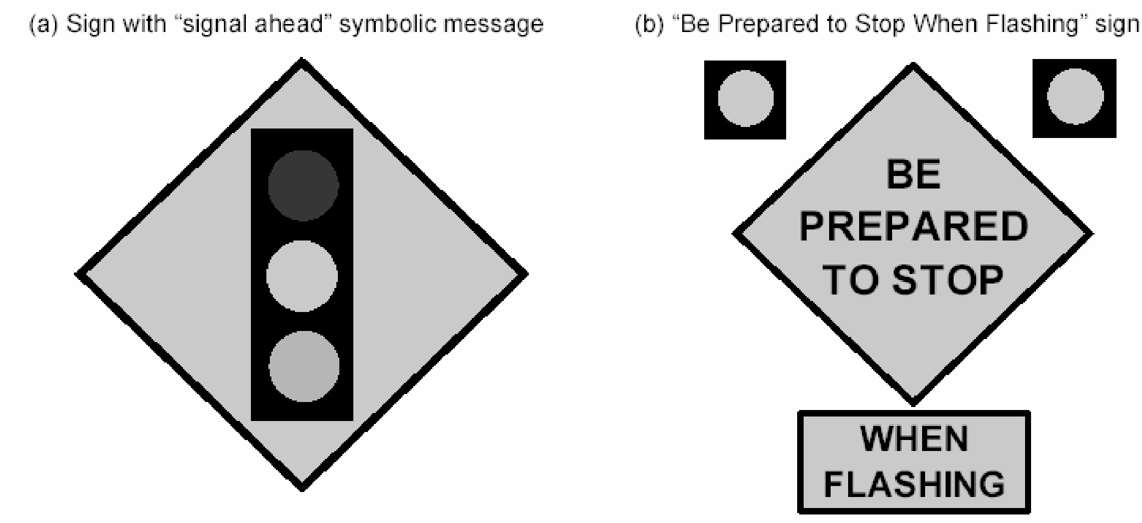

Figure 1.1: Advance warning sign and advance warning flashers

The location and timing of AWF are key considerations for the sign installation. The distance from AWF location to a signalized intersection must be equal to or greater than that required to perceive and react to the flasher and stop the vehicle safely. The timing refers to the length of time before the yellow interval of the downstream-signalized intersection at which the AWF starts flashing. Sayed et al. (1999) indicated that engineering judgment is often the principal guide for AWF installation according their literature findings. However, they also introduced practical guidelines for AWF implementation used in British Columbia, which are recommended at provincial intersection s where one of the following conditions is satisfied:

- The posted speed limit on the roadway is 70 km/h or greater,
- The view of the traffic signals is obstructed because of vertical or horizontal alignment (regardless of he speed limit) so that a safe stopping distance not available,

- There is a grade in the approach to the intersection that requires more than the normal braking effort, or
- Drivers are exposed to many kilometers of high-speed driving (regardless of posted speed limit) and encounter the first traffic signal in a developed community.

Studying drivers' responses to advance warning flashers in the field is highly problematic because these devices are relatively uncommon and because it is difficult or impossible to establish a controlled experimental environment in which variable parameters can be tested individually. Smith (2001) employed the Human Factors Research Lab's driving simulator to investigate effects of Advance Warning Flashers at signalized intersections on simulated driving performance. After analysis of the large volume of experimental data, the researchers concluded that AWFs often improve stopping behavior at suitable intersections. But as is often seen in human factors research, human response to a complex situation is not as simple as a linear relationship. In this case, variability in human response resulted in some drivers making a more aggressive—and risky—decision to proceed through the intersection. This finding has obvious implications for field implementation of advance warning flashers at dangerous intersections (Smith, 2001).

Sayed et al. (1999) utilized and analyzed data from British Columbia using two different methods. Models were used to develop expected accident rates at 106 signalized intersections for total, severe and rear-end accidents. Twenty-five of these intersections had AWFs. Although the results indicate that intersections with AWFs have a lower frequency of accidents, the difference between those with AWFs and those without is not statistically significant. An additional before-and-after study was performed for the 25 intersections equipped with AWFs to estimate the accident reduction specific to each location and its approach volumes. A correlation was found between the magnitude of the minor approach traffic volumes and the accident reduction capacity of AWFs, showing that AWF benefits exist at locations with moderate to high minor approach traffic volumes (minor street AADT of 13,000 or greater).

CHAPTER 2: DRIVING SIMULATORS

2.1 Transportation and Safety Research Application to Driving Simulators

With the progress of computer software and hardware in recent years, driving simulators are being rapidly developed (Zeng, 2002). A driving simulator is a virtual reality tool that gives a driver on board the impression that he is driving a real vehicle by predicting vehicle motion caused by driver input and feeding back corresponding visual, motion, audio and proprioceptive cues to the driver. The simulator normally consists of several subsystems as follows: a real-time vehicle simulation system performing real-time simulation of vehicle dynamics; motion, visual and audio systems reproducing vehicle motion, driving environment scenes and noise sensed by a driver during driving; a control force loading system acting as an interface between the driver and the simulator; an operator console for monitoring system operation; and system integration managing information and data transfer among subsystems and synchronization (Woon-Sung, 1998).

Today, driving simulators are widely used not only for training but also for research. They enable researchers to conduct multi-disciplinary investigations and analyses on a wide range of issues associated with traffic safety, highway engineering, Intelligent Transportation System (ITS), human factors, and motor vehicle product development (Blana, 1999). The use of a modern advanced driving simulator for human factors research has many advantages over similar real world or on-road driving research. These advantages include experimental control, efficiency, expense, safety, and ease of data collection

(Stuart, 2002). One of the obvious advantages of driving simulation is the ability to reproduce dangerous driving conditions and situations in a safe and controlled environment (Woon-Sung, 2002). Knodler et al. (2005) evaluated the operational advantages and safety of various left turn controls at signalized intersections using a driving simulator. The research consisted of seven different left turn scenarios designed in the driving simulator and the results suggested that simultaneous retrofit display may improve driver's comprehension of the permissive indication. Mitchell et al. (2005) investigated the use of a modern driving simulator as a substitute to actual field-testing. The designed scenarios in the driving simulator entailed traffic safety measures and speed reductions in work-zones and subjects speeds were recorded. This research indicated that the use of driving simulators is a promising tool for performing safety countermeasure evaluation studies. Bella (2005) validated the CRISS driving simulator by comparing the velocities on a highway next to a work zone to the velocities obtained from the driving simulator. The same highway and construction zone were designed in the driving simulator and the resulting velocities from several runs showed a statistically no difference between the velocities. Romoser et al. (2005) validated and calibrated the driving simulator and utilized it to verify the effectiveness of temporary traffic signs on highways. A survey of speeds measurements on highways next to a work zone was compared to the speeds from the design of the same highway in driving simulator. The results showed a statistically non-significant difference between both groups of speeds.

Hirata et al. (2005) tested the deterioration of the awareness level while driving in a long urban expressway tunnel using the driving simulator. The results from the driving simulator indicated that driver's awareness level could decline especially at basic segments between merging/diverging sections. The results also indicated that an audio information system that provides warning messages before drivers enter merging/diverging sections could prevent a deterioration of the awareness level.

Lambert et al. (2005) measured the driving performance and eye glance behavior using a driving simulator. The experiment results relied on comparing the results of the control case where no tasks were required on the driver to the test case where drivers operate with radio functions, reading a map and a paper etc.

Cody (2005) conducts several field tests to support the design of an intersection crash countermeasure system using a driving simulator. The results present the organization of the intersection approaches in four categories: driver turns without stopping; diver stops before intersection and then turns without stopping; driver stops before intersection and in the intersection; and driver stops in the intersection. The results indicate that speed and/or acceleration profiles are the parameters to use for countermeasure design in order to determine when a driver decides to cross an intersection.

2.2 The UCF Driving Simulator

The driving simulator acquired by the Center for Advanced Traffic System Simulation (CATSS) at the University of Central Florida is able to generate real life driving conditions. A passenger car (Saturn sedan) is mounted on a motion base providing the drivers with the same real car motions on the roads as shown in Figure 2.2.1 below.

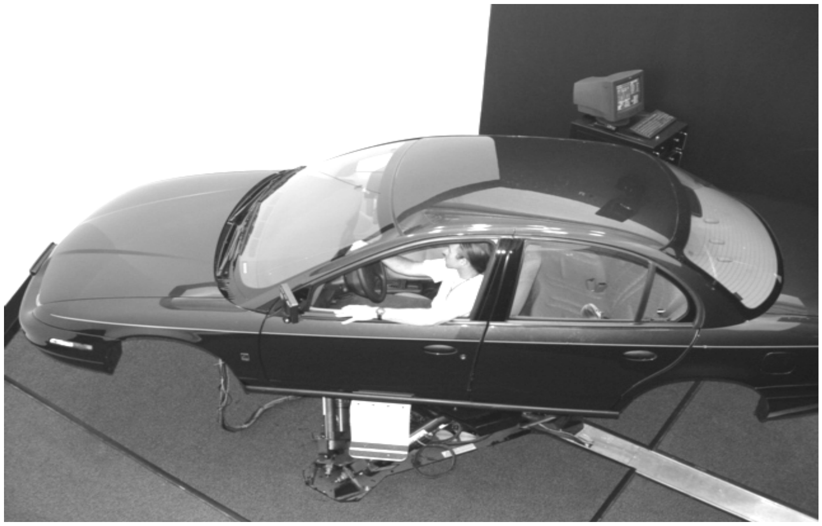

Figure 2.2.1: Saturn Sedan mounted on a motion base.

The simulator car includes five channels of image generation (1 forward, 2 side views, and 2 rear mirrors), an audio and vibration systems, and steering wheel feedback illustrated in Fig. 2.2.2 below.

Figure 2.2.2: Five channels of image generation

The simulator allows simulations with different types of vehicles and has sophisticated vehicle dynamic models for different vehicle classes. The simulator also comprises of a visual database such as rural, suburban and freeway roads plus an assortment of buildings and operational traffic control devices. Other features include the ability to implement vehicle system malfunctions, and to control the weather conditions (sunny, rain, snow). The scenario generation editor allows us to program the vehicles to follow specific routes, adhere to certain driving patterns, appear at specific points according to a predefined schedule or be a triggered based on other events within the simulation. Another class of vehicles can also be defined to serve as ambient traffic with random movements, making the overall driving experience in the simulator more realistic. Different types of vehicles such as passenger cars, buses, ambulance, police cars, and trucks are user selectable for scripted and random movements throughout the database.

The simulator session is controlled from an operator's console in an adjacent control room. The five video channels are monitored on computer screens in the control room as shown in Figure 2.2.3. A road map of the database is viewable on the operator's console showing the movement of the simulator vehicle and other vehicles that are present as shown in Figure 2.2.4.

Figure 2.2.3: Operator’s room

Figure 2.2.4: Real-time map.

Scenarios are created with the scenario editing software on a screen showing the location of roads, buildings, traffic control devices, and pedestrians. In addition the five video channels and the real-time map, a camera was installed inside the simulator car to allow supervise the driver's responses in the car, and an emergency stop button is provided in the control room, shown in Figure 2.2.3 to immediately discontinue the driving if the driver suffer a motion sickness.

2.3 Previous research in the UCF driving simulator

The driving simulator is capable of supporting research in driving simulation, driver training, human factors and traffic engineering. Two research projects, made possible by the scenario generation software, have been conducted with a main concern of improving driving safety.

Researchers from Georgia Tech Research Institute (GTRI) conducted a US Department of Transportation (DOT) funded study to evaluate the Safety Warning System (SWS), which provides an inexpensive and efficient warning for drivers. Over the last two years 4 million SWS enabled radar detectors were sold in the United States that had a significant crash reduction. A test plan was formulated by GTRI and UCF personnel to utilize the UCF driving simulator to evaluate driver responses and behaviors to SWS warnings under various scenarios and traffic incidents. The objective of the study was to explore whether drivers' response and performance is affected by SWS warnings is useful the driver should have shorter response times and make better decisions.

The second research project, conducted by Xuedong Yan, used the UCF driving simulator as a vehicle quantifying the minimum acceptable gaps for a left turn from a minor road at a two way stop-controlled intersection with 25 and 55 mph. The driving simulator's experiment results showed that the critical gap for the 25 mph speed major traffic is 7.31 sec and the critical gap for the 55 mph speed major traffic is 5.78 sec.

CHAPTER 3: EXPERIMENT METHODOLOGY

3.1 UCF driving simulator

The driving simulator is an STS Mark-III system, which consists of a simulator cab, Simview, Mdyn, motion base, scenario editor, operation console and Application Programmer Interface (API) for reading real-time data.

- Simulator Cab: It is a Saturn model that has an automatic transmission, air conditioning, a left back view mirror and a center back view mirror inside the cab, as shown in Figure 3.2.1.1.
- Simview: The software that generates the graphical display.
- Mdyn makes the driving of the simulator car realistic. It takes care of the physical feeling of the driving. It also communicates with API, Motion base, and Simview.
- Motion base: It provides motion, when the driver is driving. It plays a very important role on driving fidelity during the simulation. It provides six degrees of freedom (roll, pitch, heave, and yaw).
- Scenario Editor: It is very important software, which stores all types of roads, buildings and other physical features of the roads. In addition, traffic signs and ambient traffic can be laid out based on scenarios.
- APIs for reading real-time data: Currently, APIs can read real-time data from Simview. The data include steering wheel, accelerator, brake, vehicles' speeds and coordinates at 30 HZ frequency.

3.2 Experimental Design

3.2.1 Horizontal Visibility Blockage

A typical rear-end collision due to horizontal view blockage occurs as the procedure described in Figure 1. Initially, the leading vehicle is traveling at a cruising speed (35mph) followed by another vehicle keeping following-car headway. At the time (T0), a hazardous event hinders the leading vehicle, which is an opposing vehicle unexpectedly and suddenly turning left in front of the leading vehicle in our scenario design as shown in the AutoCAD drawings below (Figure 3.2.1.2 and Figure 3.2.1.3). At moment (T1), the driver in the leading vehicle starts to sharply decelerate to avoid the accidents after response time (T1-T0). For the following vehicle, there are two possibilities in response to this event. One is that the following driver could not see what happened beyond the leading vehicle, and then he/she had to decelerate at T2 moment to avoid collision after realizing the leading vehicle's urgent deceleration. The other possibility is that the following driver can see the event happened beyond the leading vehicle at T0 and also realizes the potential danger ahead, and he/she decelerates at T3 after his/her response time (T3-T0). Generally, T3 is shorter than T2, even maybe shorter than T1 because the following-car driver also makes a direct response to the first event happened in front of the leading vehicle. Therefore, if the time interval T3-T1 (it can be a negative value) is smaller than T2-T1, one can conclude that view blockage of the leading vehicle has more contributions to the potential rear-end collision.

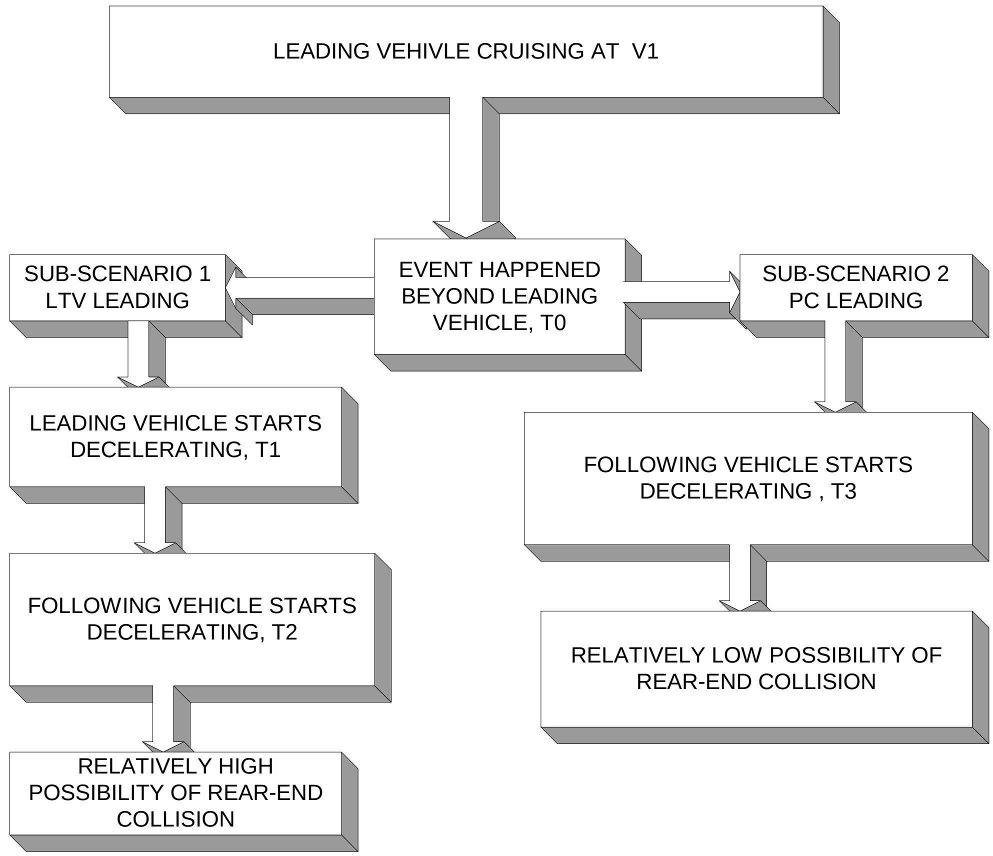

Figure 3.2.1.1: Diagram for first scenario (horizontal view blockage)

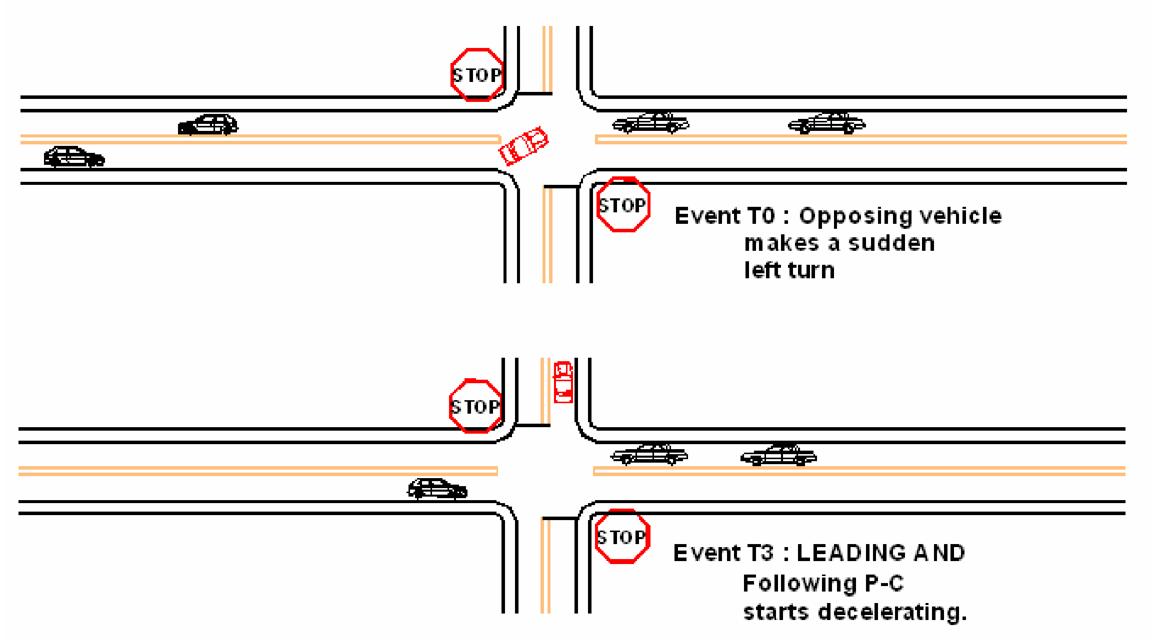

Figure3.2.1.2: Sub-Scenario 1 (simulator car following a passenger car)

As shown in sub-scenario-1 above which is the base or control sub-scenario of the horizontal visibility blockage scenario, the leading passenger car does not obstruct the following passenger car driver's visibility. Therefore, at T0 when an aggressive driver from the opposite direction makes a sudden left turn, the leading and following passenger cars drivers can react at the same time, though decreasing the probability of rear-end collision. The second picture in the above Figure shows that both vehicles come to a stop without an accident.

In Figure 3.2.1.3 below, which is the test sub-scenario of the horizontal visibility blockage scenario, the front vehicle is the LSV and the rear vehicle is the passenger car (the simulator). As shown, at time T0 when the car from the opposite direction makes a sudden left turn, the leading vehicle which is the LTV reacts to the event and the following passenger car won't react until time T1 when its driver perceives the leading vehicle's braking light. The following vehicle starts

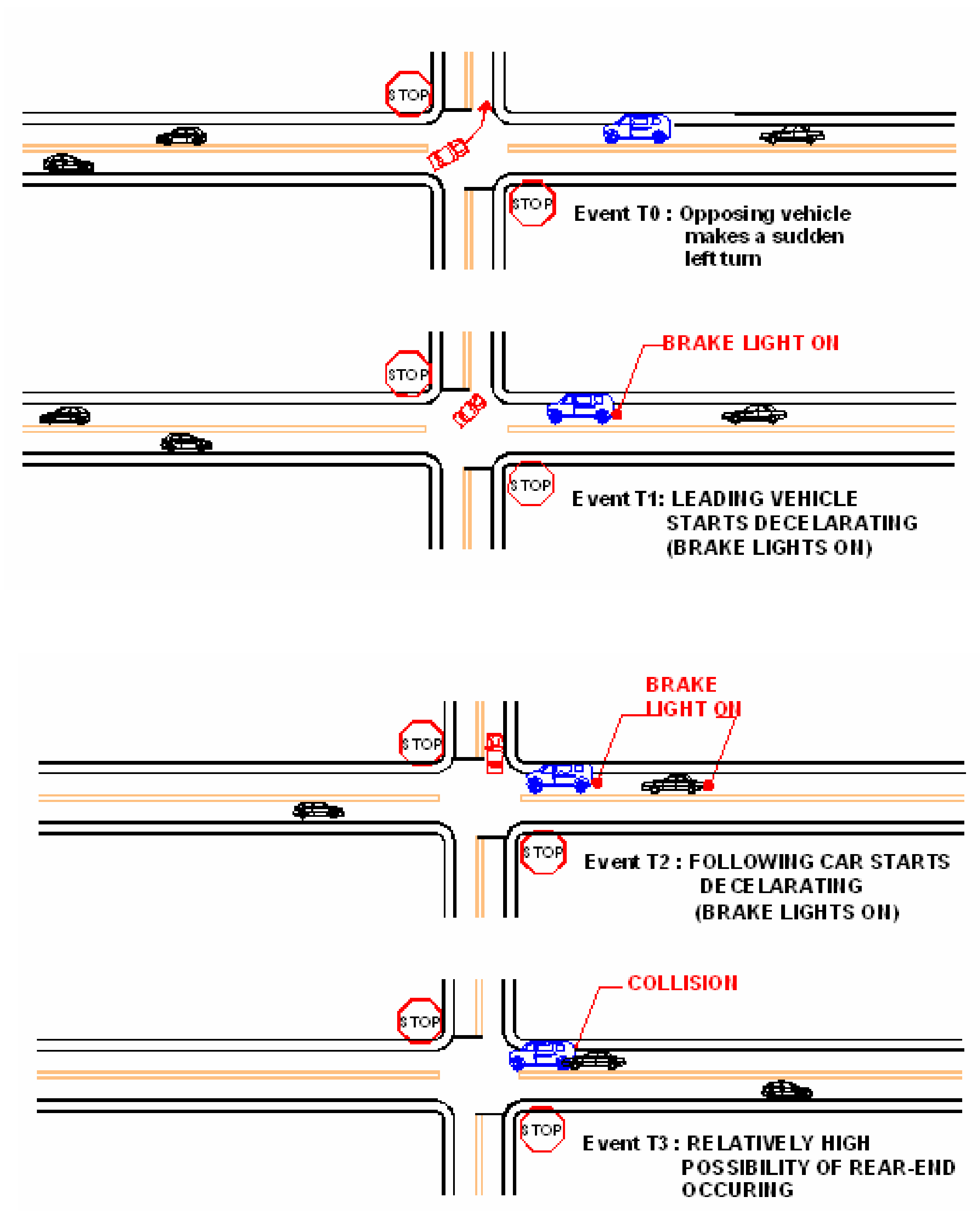

Figure 3.2.1.3: Sub-scenario 2

braking at T2 and comes to a complete stop at T3 where there will be a high risk of rear-end collision.

3.2.2 Vertical Visibility Blockage

A typical red light running due to vertical view blockage occurs as the procedure described in Figure 3.2.2.1. Initially, the leading vehicle (LSV) is traveling straight ahead at a cruising speed (35 mph) followed by another vehicle keeping following-car headway through a signalized intersection. At the time T0, the traffic signal turns from green to amber. At that time the leading vehicle which is at a safe distance to cross the intersection, decides to cross the intersection. However, the following vehicle is not at a safe distance to clear the intersection and is also not aware of the traffic signal change. At T1, 3.5 seconds (assumed time for amber light) after T0, the Traffic signal turns red leaving almost no time for the following vehicle to react and stop safely. At time T2, the following vehicle reacts and is faced with two alternatives. The drivers can either suddenly stop leading to possible rear-ends or run the red light also leading to possible accidents at the intersection.

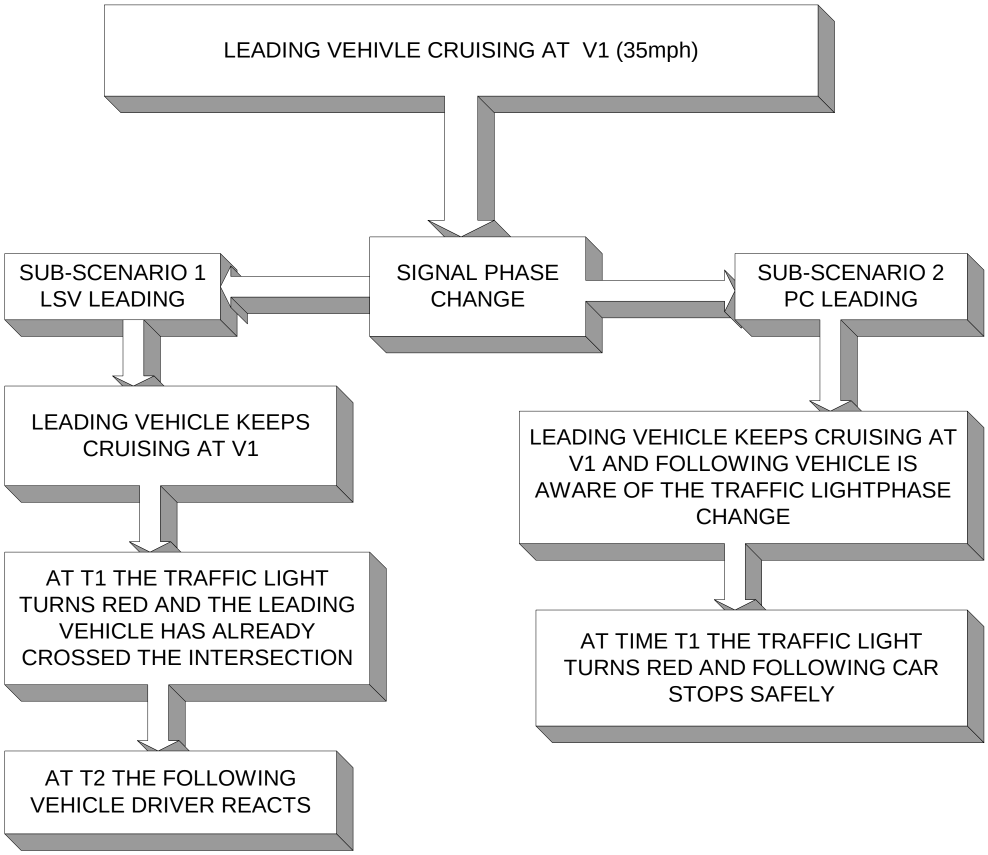

Figure 3.2.2.1: Diagram for second scenario (vertical view blockage)

Similarly to the horizontal visibility blockage scenario, the vertical visibility blockage scenario consists of two sub-scenarios. Sub-scenario 1 is illustrated in Figure 3.2.2.2 above and serves as the control or base sub-scenario.

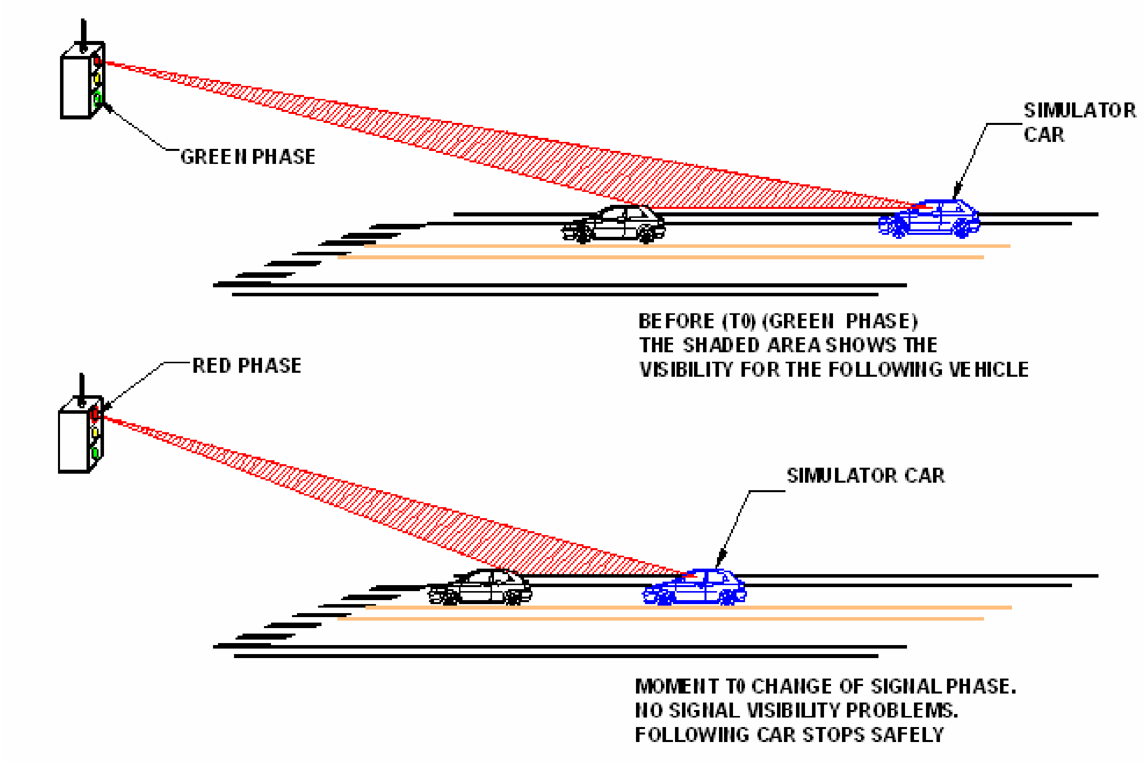

Figure 3.2.2.2: Sub-Scenario 1 (simulator following passenger car)

Sub-scenario 2, illustrated in the Figure 3.2.2.3 below, serves as the test sub-scenario. In both Figures the shaded region represents the visible region for the following car driver. In the above Figure, the following passenger car, the simulator car, can clearly see the traffic signal. Therefore at time T0 when the signal phase changes, both the following and the leading vehicles' perceive the event and react at time T3. However as shown in Figure 3.2.2.3 below, the LSV obstruct the vertical visibility for the following passenger car driver and disable him from seeing the traffic signal.

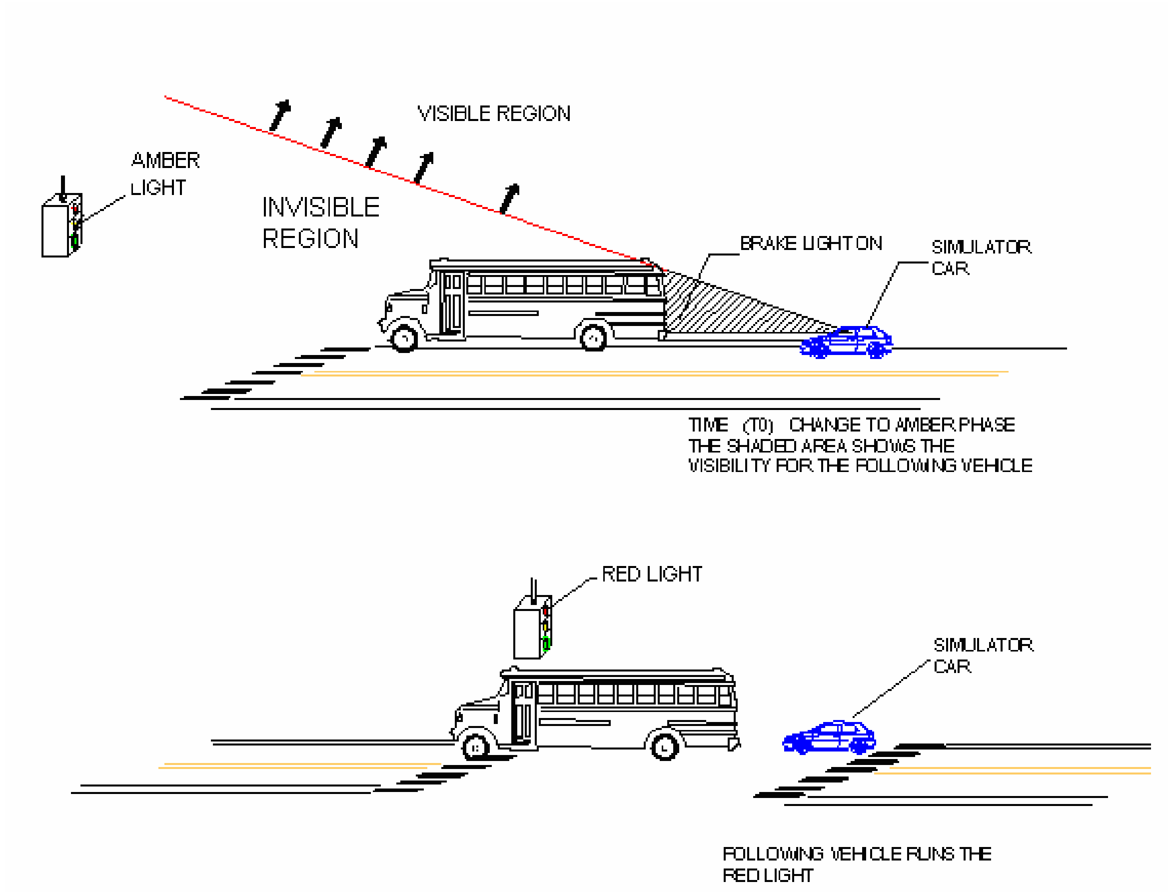

Figure 3.2.2-3: Sub-Scenario 2 (simulator following school bus)

Therefore, at time T0, when the signal phase changes, the leading vehicle, LSV, reacts at time T1, T1-T0 seconds after T0 and slams on his brakes to avoid running the red light. Therefore, the following vehicle driver who was not aware of the event happening at T0, reacts at T2 when he perceives the brake light, T2-T1 seconds after the leading vehicle reacts, and slams on his brakes at T3. Therefore, the following vehicle will have T2-T1 seconds less than the leading vehicle to come to a complete stop without colliding with the leading vehicle. These sequences of events lead to a high probability of rear-end collisions and to red light running in case the leading vehicle decides to cross the intersection.

A third scenario is suggested to solve the vertical visibility blockage, where a traffic signal pole is placed on the right side of the road upstream of the intersection. Figure 3.2.2.4 describes the suggested solution.

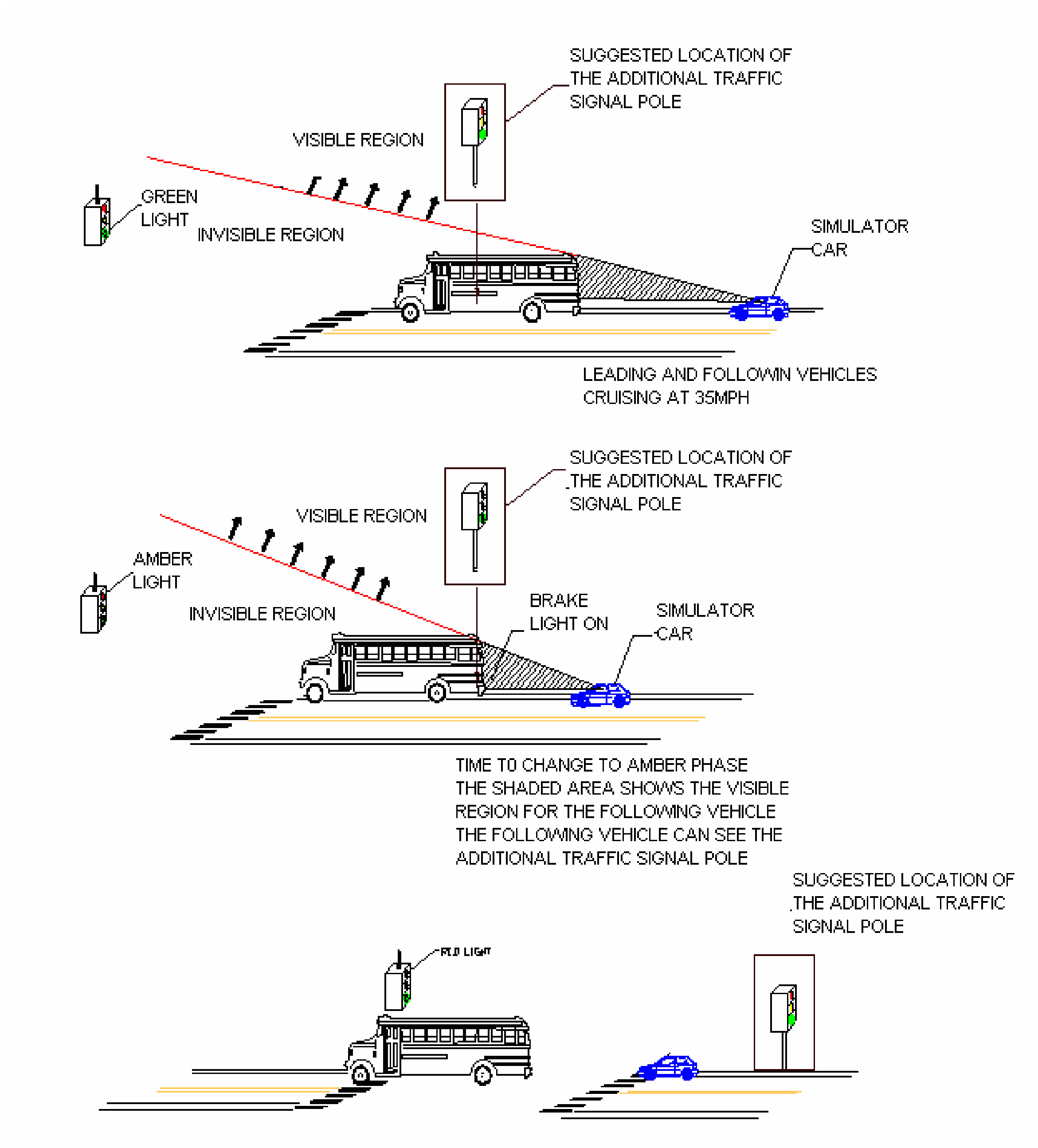

Figure 3.2.2.4: Suggested solution for the vertical visibility blockage problem

3.3 Simulation Scenario Design

3.3.1 Horizontal Visibility Blockage Scenario

The horizontal view blockage scenario consisting of two sub-scenarios, a base or control sub-scenario and a test sub-scenario discussed previously is designed in the driving simulator. The whole experiment course can be described in three stages as shown in Figure 3.3.1.1. In the first stage, the driver in the simulator car cruises on a four-lane urban road with a 45 mph posted speed limit and the traffic in the scene is assigned to flow at 45 mph. The purpose of this design is to make the simulator car divers adapt to relatively higher speed traffic. At the second stage, the simulator car approaches the signalized intersection and stops at the red phase behind the LTV, which is assigned to be there. When the light turns green the LTV is assigned to cruise at a 35 mph, following the speed limit, while the following vehicle, accustomed with the higher speed limit follows him with a velocity tending to be greater than the speed limit. Moreover, the two-lane road in the direction of the simulator is dropped to 1 lane to inhibit any passing between vehicles. Therefore, the simulator car driver is forced to drive behind the LTV until the two-way stop intersection in the third stage. As mentioned before, the width of the LTV will be 1.88 m while the width of the passenger car will be 1.70m and the assigned deceleration rate for the leading vehicle is 0.8g.

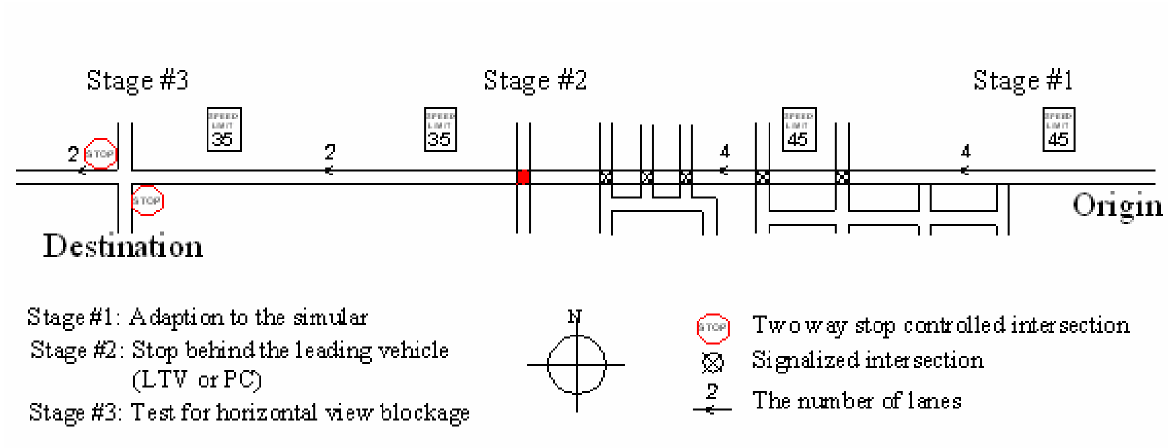

Figure 3.3.1.1: Horizontal visibility scenario three stages

Figures 3.3.1.2 and 3.3.1.3 are snapshots taken during the horizontal visibility blockage scenario and they represent the starting point of the experiment, the time where the simulator car comes behind the LTV, and the left turn the vehicle from the opposite direction makes.

Figure 3.3.1.1: Point where simulator car comes behind the LTV (Stage 2)

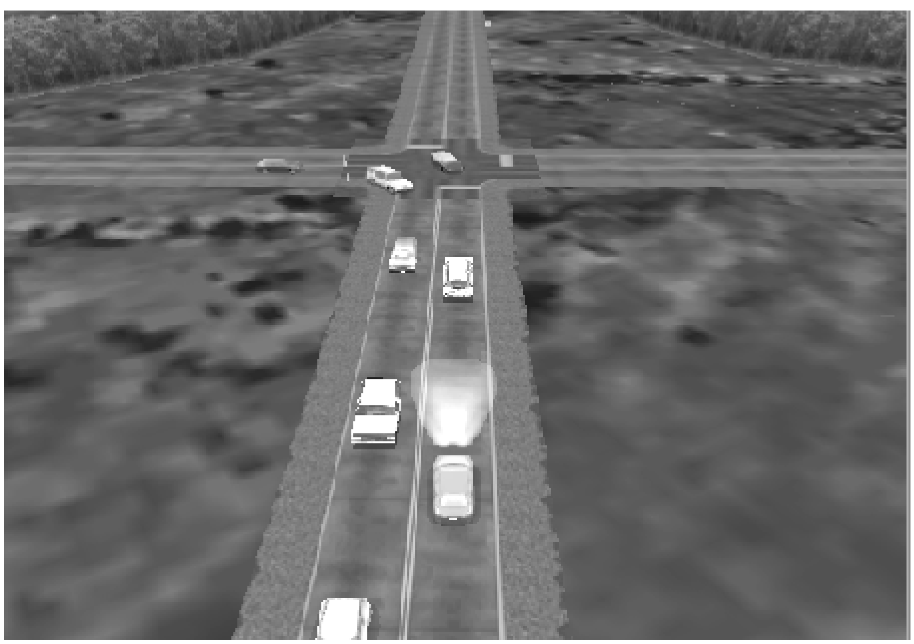

Figure 3.3.1.2: Point where opposing vehicle makes a left turn (Stage 3)

3.3.2 Vertical Visibility Blockage Scenario

The vertical view blockage scenario that consists of two sub-scenarios, a base or control sub-scenario and a test sub-scenario, as discussed previously, is designed in the driving simulator. The whole experiment course can be described in three stages as shown in Figure 3.3.2.2. In the first stage, the subject drives his car to a T-intersection where he/she is instructed to make a left. The purpose of this design is to make the simulator diver drive slowly until he gets to stage 2. At the second stage, the simulator car approaches the signalized intersection, where the phase has just turned green and where a school bus just started making a right turn slowly. The subject is assigned to make a right turn at that intersection. The purpose of this design is to make the simulator car drive closely behind the school bus since the latter makes very slow turns therefore the simulator will be tailing him. The speed limit at the second stage is 35 mph which will also make the subject drive closely behind the school bus since the latter reaches the cruising velocity very slowly. At the second stage also the route is one lane pr direction for the reason of inhibiting the following car from passing the leading car. Finally, in the third stage, as discussed before, the traffic signal turns amber and the behavior, such as gap and velocity, of the subjects is collected for analysis.

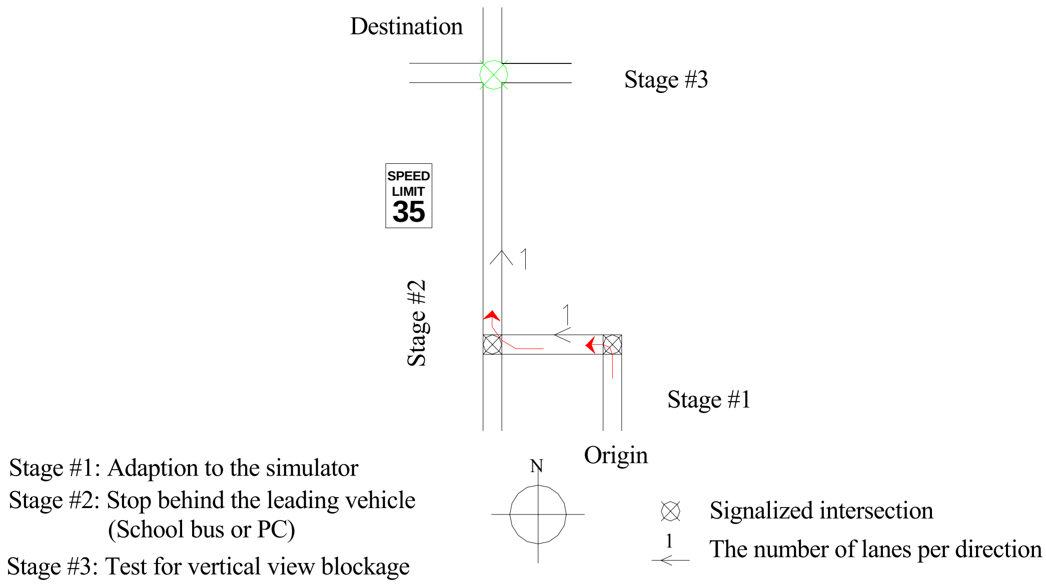

Figure 3.3.2.1: Vertical visibility scenario three stages

Figure 3.3.2.2 and 3.3.2.3 show respectively a top view when the simulator makes a left turn behind the bus and an in-cab view when the simulator approaches the intersection behind the bus. As seen in Figure 3.3.2.3 the traffic signal is invisible.

Figure 3.3.2.2: Making a right turn behind the bus

Figure 3.3.2.3: Approaching intersection behind the bus

CHAPTER 4: THEORETICAL CALCULATIONS

4.1 Vertical Visibility Blockage

In this section, theoretical calculations were completed to compute the minimum gap X1, shown in the Figure below, at which the traffic light is visible for the following vehicle driver. In these calculations, the height of the LSV, the eye height of the following driver, and the height of the traffic light were standard values borrowed from AASHTO standards.

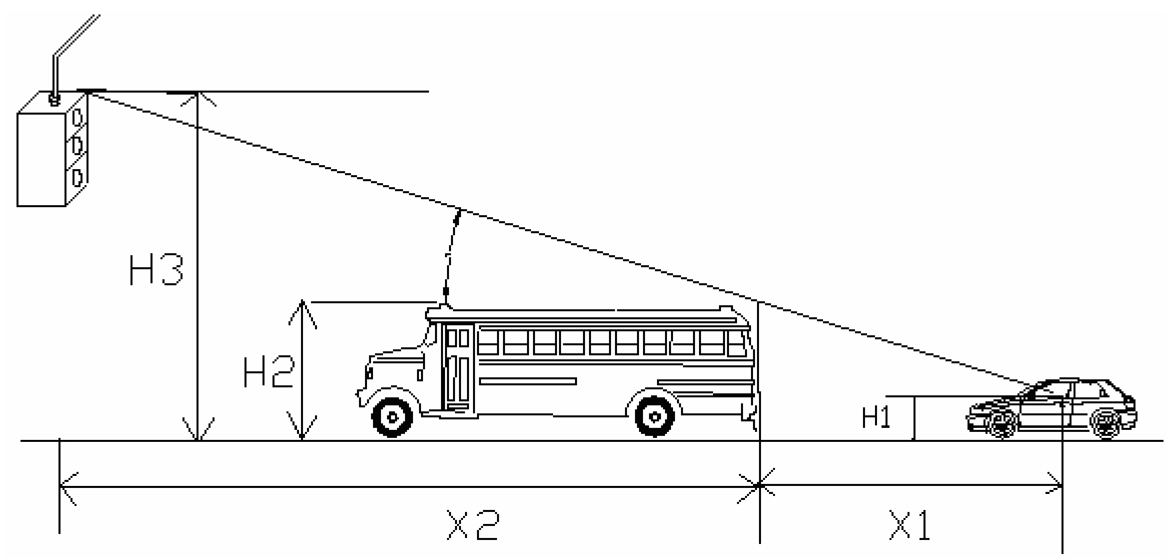

Figure 4.1.1: Vertical visibility blockage calculations

From the trigonometry of the Figure 4.1.1 the following equations were computed:

$$\frac{H2 - H1}{X1} = \frac{H3 - H2}{X2}$$

$$H3 = \frac{X2}{X1}(H2 - H1) + H2$$

We would like: $\frac{X2}{X1}(H2 - H1) + H2$ to be < *H3*

$$X2 = vt + \frac{v^2}{2a} + w + L + D$$

Where,

H2 is the LSV height and an average value of 8.5 ft is used in the experiment.

H3 is the signal head height and an average value of 21 ft is used in the experiment (AASHTO).

H1 is the eye elevation equal to 3.75 ft (AASHTO)

W is the width of the intersection 40 ft (AASHTO)

L is the length of the vehicle taken 30 ft (AASHTO)

D is the set back of the stop bar from the intersection, which is 10 ft

t is the standard response time which is 1.0 s (AASHTO)

a is the acceleration rate taken 10 ft/s^2 (AASHTO)

X1 is the distance from the center of the car to the back of the front vehicle in ft.

X2 is the Distance from the back of the leading vehicle to the traffic signal.

V is the velocity of the vehicle taken 35 mph or 51.33 feet per second

Table 4.1.1 shows the minimum required distance X1, which is the distance between the leading and the center of the following vehicle, with the variation of the traffic light height H3 and the LSV height H2 using the equations listed above. From the below table, the values of X1 are proportional to H2 and H3. Indeed, the bigger H2 and H3 the larger X1 must be in order for the following vehicle driver to see the traffic light. In the formal experiment we used H2 = 8.5 ft and H3= 21ft. For instance, from the below table when H2 = 9ft and H3= 18 ft the minimum distance X1 must be 187 ft in order for the following vehicle driver to see the traffic light.

Table 4.1.1: Variation of X1 with H2 and H3

V	T	w	A	L	D	H1	H2	H3	x2	x1
51.33	1	40	10	30	10	3.75	9	18	320	187
51.33	1	40	10	30	10	3.75	9	20	320	153
51.33	1	40	10	30	10	3.75	9	22	320	129
51.33	1	40	10	30	10	3.75	10	18	320	250
51.33	1	40	10	30	10	3.75	10	20	320	200
51.33	1	40	10	30	10	3.75	10	22	320	167

4.2 Horizontal visibility blockage

For the horizontal visibility blockage similar trigonometry calculations were applied. Several assumptions were made; the width of the LSV will be 1.8 m (or 5.91 ft) and the width of each leg of the intersection is 24 assuming that each lane is only 12 ft.

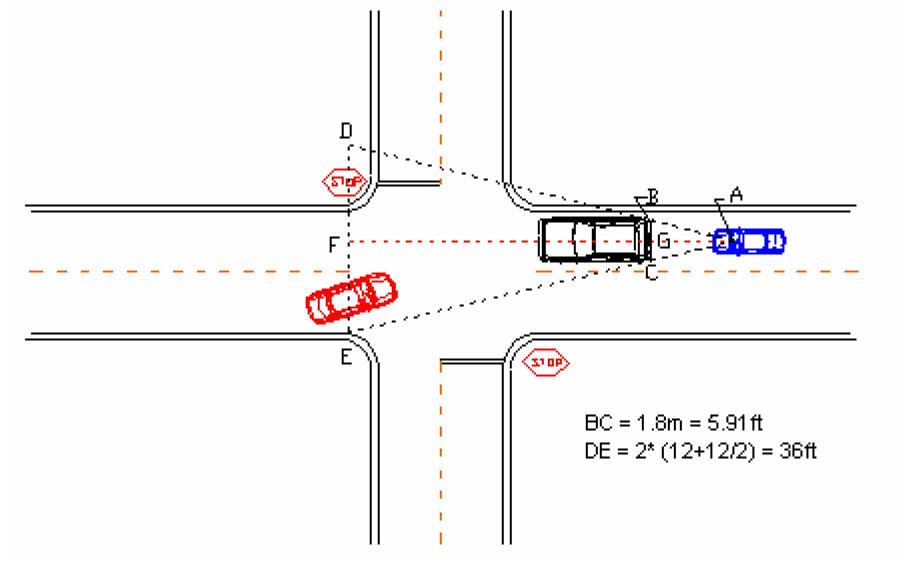

Figure 4.2.1: Horizontal visibility blockage calculations

Therefore, assuming that the simulator vehicle drives in the center of the lane, the length of DE is $2*(12+\frac{12}{2})=36\,ft$. In the triangles ABC and ADE the following ratios can be applied:

$$\frac{BC}{DE}=\frac{AG}{AF}=\frac{AF-GF}{AF} \qquad (4.2.1)$$

We would like $\frac{(BC*AF)}{(AF-GF)}<DE \;\rightarrow\; \frac{(5.91*AF)}{(AF-FG)}<36$

$$GF=vt+\frac{v^2}{2a}+w+L+D \qquad (4.2.2)$$

Where,

w is the width of the intersection 24 ft (each lane is assumed to be 12 ft)

L is the length of the vehicle taken 30 ft (AASHTO)

D is the set back of the stop bar from the intersection, which is 10 ft

t is the standard response time which is 1.0 s (AASHTO)

a is the acceleration rate taken 10 ft/s2 (AASHTO)

AG is the distance from the center of the car to the back of the front vehicle in ft.

GF is the Distance needed to clear the intersection during the amber phase.

v is the velocity of the vehicle taken 35 mph or 51.33 feet per second

$$GF = (51.33 * 1) + \frac{51.33^2}{2 * 10} + 24 + 30 + 10 = 247.07 \text{ ft}$$

$$\frac{(5.91 * AF)}{(AF - 247.07)} < 36 \rightarrow 5.91 * AF < 36 * (AF - 247.07)$$

$$AF < 295.60\, ft$$

Form our calculation, if AF is less or equal to 295.60 ft the following car driver cannot see a vehicle making a sudden left turn in front of the lead vehicle as shown in Figure 4.2.1.

CHAPTER 5: DATA COLLECTION METHOD

5.1 Simulator data collection

The driving simulator data collection software gathers a variety of data. First, when the scenarios are designed, the velocities and the coordinates values are preset for the surrounding traffic in the experiment. The data collection software is able to collect the following simulator car data from which other data can be derived with time interval 1/30 seconds:

1. The Velocity of the simulator car and the velocity of any other significant vehicles.
2. The Acceleration of the simulator car.
3. The Braking input: a percent value relative to the maximum braking
4. Steering input: the angle by which the steering wheel is turned.
5. X-Y coordinates of the center of the driving simulator and other significant vehicles.

The collected data is extensively discussed in chapter six of this thesis.

5.2 Pilot Study

Before starting the formal experiment, a pilot study was conducted for the horizontal view blockage scenario consisting of two sub-scenarios. Figure 5.2.1 illustrates both sub-scenarios. As explained before, the first sub-scenario serves as base scenario and the second sub-scenario serves as a test scenario. As shown in the Figure below wider vehicle will block a wider angle for the following vehicle driver.

The purpose of the pilot study was to test the design of the experiment and to calculate the sample size needed in the formal study. Moreover, the pilot study tested the primary suggested data collection method.

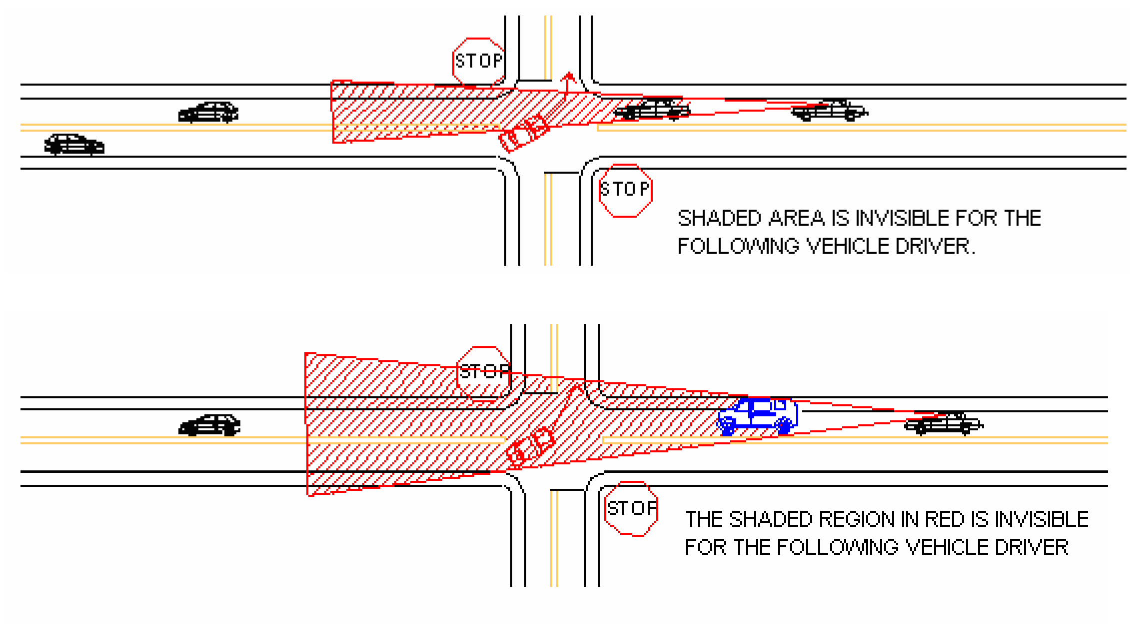

Figure 5.2.1: Horizontal visibility blockage sub-scenarios

5.2.1 Data Collection

In our primary suggested data collection method, ten individuals drove the simulator car for each of the sub-scenarios described in the Figures above. The same subjects drove both sub-scenarios. To analyze any bias in the data collection method, 5 subjects started by driving the SIM-LTV sub-scenario (simulator car following an LTV) then the SIM-PC (simulator car following a regular passenger car) which is called sequence “1” in table 5.2.2.1, and the five remaining individuals started with SIM-PC then SIM-LTV, which is called sequence “2” in table 5.2.2.1. The purpose of this approach was to ensure that both sub-scenarios are treated equally.

Table 5.2.2.1 summarizes the data collection and the information about the drivers. The first column of the table contains the names of the drivers; the second column describes the sequence of scenarios each driver followed. The third column of the table tells us about whether there has been a rear- end collision for each scenario, and columns 4 and 5 provide the age and the gender of the drivers. For example, “Chady” followed sequence 2 which means that he started with the SIM-PC sub-scenario followed by SIM-LTV sub-scenario. In the third column we see (NO/NO), which means that “Chady” did not have an accidents in either scenarios.

5.2.2 Pilot study analysis

From table 5.2.2.1, the following cases are analyzed:

1. Testing the statistical significance difference between the number of potential rear-end collisions between the SIM-PC sub-scenario and the SIM-LTV sub-scenario.
2. Testing the statistical significance difference between the number of potential rear-end collisions between SIM-PC and SIM-LTV for starting with the SIM-LTV sub-scenario and starting with the SIM-PC sub-scenario.
3. Testing the statistical significance difference between potential rear-end collisions of following an LTV if the driver starts with SIM-LTV and potential rear-end collisions of following an LTV if the drivers starts with SIM-PC

Table 5.2.2.1: data collection summary and drivers information

Sequence 1: SIM-PC / SIM-LTV Sequence 2: SIM-LTV / SIM-PC				
Name	Sequence	Accident First / Accident second	Gender	Age
Chady	2	No/No	M	18
George	1	No/No	M	23
Johan	1	Yes/No	M	22
Kathy	1	No/Yes	F	19
Shannon	2	Yes/No	F	22
Zack	1	Yes/No	M	25
Lori	2	Yes/No	F	19
Ghada	2	Yes/No	F	26
Ghalib	2	Yes/No	M	29
Yanf	1	No/No	M	29

Table 5.2.2.2: Summary of MINITAB output for the Above Cases

NUMBER 1	H0: P1=P2 H1: P1≠P2	P-VALUE = 0.138	95% CONFIDENCE A =0.05	DON'T REJECT H0
NUMBER 2	H0: P1=P2 H1: P1≠P2	P-value = 0.157	95% Confidence α =0.05	Don't Reject H0
NUMBER 3	H0: P1=P2 H1: P1≠P2	P-value = 0.000	95% Confidence α =0.05	Reject H0

The three statistical tests of significance were completed using the MINITAB software and table 5.2.2.2 summarizes the results. Appendix E contains the MINITAB output for the pilot study in details.

In the first test, the proportions of crashes of SIM-LTV and SIM-PC sub-scenarios were tested and the resulting P-value = 0.138 > α = 0.05. H0 is not rejected and there is no statistically significant difference between the 2 proportions. However there is a marginal statistical difference between the two ratios.

For the second test, the proportions of potential rear-end collisions of SIM-LTV sub-scenario (only for scenarios starting with LTV) and SIM- PC sub-scenario (only for scenarios starting with PC) were tested and the resulting P-value = 0.157 > α = 0.05. Ideally, H0 is not rejected and there is no statistically significant difference between the 2 proportions, which suggests a marginal statistical difference between the two population proportions. In the formal study with larger sample size, it is also possible to have a statistically significant difference between the two population proportions. The purpose of the second test is to eliminate any bias in the data collection where we only took into consideration the first scenario of each sequence and analyzed the statistical difference.

As for the third test, the proportions of potential rear-end collisions of SIM-LTV sub-scenario (only for scenarios starting with LTV) and SIM-LTV sub-scenario (only for scenarios starting with PC) were tested and the resulting P-value = $0.00 < \alpha = 0.05$. The null hypothesis is rejected; therefore there is a statistically significant difference between the 2 proportions. From this test, it is concluded that there is a bias in the data collection because the proportions of potential crashes for the same scenario but with different sequence were tested. This test is very important because it confirms that there is a bias in the data collection. Therefore, the collected data is not very accurate and some modifications must be applied to the scenario design.

5.2.3 Variables analysis

As mentioned in section 5.1, several variables were collected and stored. As for the pilot study three main variables were collected and summarized in table 5.2.3.1 for each driver. Three paired t-tests were performed on each of the parameters to study the statistically significant difference between the means of the parameters for SIM-PC and SIM-LTV sub-scenarios.

Table 5.2.3.1: Variables results

SIM-PC			
Name	Time Difference (sec)	Average Deceleration Rate (%)	Gap (m)
Chady	2.3833	99	13.36
Ghalib	4.0166	59.54	107.786
Johan	2	86.69	17.7949
Zack	2.5167	83.61	43.7773
YanF	1.4833	63.8	20.7803
George	2.35	93.7	74.7575
Ghada	3.15	83.2	63.926
Kathy	2.75	50.91	89.1377
Lori	1.0167	78.2	53.3975
Shannon	2.4233	82.1	48.77
SIM-LTV			
Chady	2.6668	24.75	34.2715
Ghalib	3.1499	94.66	64.0254
Johan	1.5833	44.64	89.2824
Zack	3.1667	95.6	61.4824
YanF	2.8	94.48	69.0586
George	1.0334	52.94	47.0635
Ghada	2.43335	67.49	34.4277
Kathy	1.96668	70.29	46.0225
Lori	1.55	90.46	24.4473
Shannon	1.73331	90.09	27.2471

Table 5.2.3.2: Statistical summary of the paired t-tests on the parameters

TEST FOR GAP	H0: MEAN1=MEAN2 H1: MEAN1≠MEAN2	P-VALUE = 0.766	95% CONFIDENCE A=0.05	DON'T REJECT H0
Test for Time Difference	H0: Mean1=Mean2 H1:Mean1≠Mean2	P-Value = 0.576	95% Confidence α=0.05	Don't Reject H0
Test for Deceleration Rate	H0: Mean1=Mean2 H1:Mean1≠Mean2	P-Value = 0.560	95% Confidence α=0.05	Don't Reject H0

From the above table, it is concluded that there is no statistically significant difference in the gap, time difference, and deceleration rate between SIM-PC and SIM-LTV. Those results are explained by the bias of the data explained before.

The data collection is very delicate, the subjects cannot drive both sub-scenarios simultaneously because the results can be biased, thus discrediting the study results. For the formal study, there were five sub-scenarios in total. Two sub-scenarios for the horizontal visibility blockage scenario and three sub-scenarios for the vertical view blockage scenario. Since it appears from the pilot study that a subject cannot drive more than one sub-scenario in each scenario, the subjects were classified in three groups. The first group (group A) will drive the SIM-PC sub-scenario from the horizontal view blockage scenario and SIM-LSV sub-scenario from the vertical view blockage scenario.

The second group (group B) will drive the SIM-LTV sub-scenario from the horizontal view blockage scenario and the SIM-PC from the vertical view blockage scenario. Finally the third group (group C) will only drive the simulator car following a truck with the additional traffic signal pole sub-scenario from the vertical visibility blockage scenario.

5.3 Sample size

The pilot study was performed for the sake of testing the experiment and enhancing the scenario design. The pilot study also demonstrated that the data collection is very sensitive and must be completed carefully as mentioned before. Moreover, from the pilot study, the required number of subjects was determined. As mentioned before, there was no significant difference between the numbers of potential rear-end collisions between SIM-LTV and SIM-PC sub-scenarios for the horizontal visibility blockage scenario using a 95% confidence interval. The obtained P-value was 0.138 which is greater than α =0.05. However, the sample size N =10 is quite small. The size of the sample that leads to a P-value < 0.05 is calculated below.

$$n = \frac{(Z_\alpha + Z_\beta)^2 (p_1 q_1 + p_2 q_2)}{(p_1 - p_2)} \qquad (5.3\text{-}1)$$

Where:

n = Estimated necessary sample size.

Z α = Z-coefficient for the false-change (Type I) error rate from the table below. In our case with 95 % confidence interval, α=0.05 and Z α= 1.96 from table 5.3.1.

Z β = Z-coefficient for the missed-change (Type II) error rate from the table below. In our case with 95 % confidence interval, β =0.05 and Z β = 1.64 from table 5.3.1.

p1 = the value of the proportion for the first sample as a decimal. In our case, the first sample is Sequence 1 defined previously as (SIM-LSV)/(SIM-PC) in table 5.2.2.1 . And p1 is defined in the equation below:

$$p1 = \frac{Number\_of\_LTV\_Accients}{Total\_Number\_of\_Trials} = \frac{4}{5} = 0.8$$

q1 = 1 - p1. =1- 0.8 = 0.2

p2 = the value of the proportion for the second sample as a decimal. In our case, the first sample is Sequence 2 defined previously as (SIM-PC)/ (SIM-LSV). And p2 is defined in the equation below:

$$p2 = \frac{Number\_of\_PC\_Accients}{Total\_Number\_of\_Trials} = \frac{2}{5} = 0.4$$

q2 = 1 - p2. = 1 – 0.4 = 0.6

$$n = \frac{(1.96 + 1.64)^2 (08 * 0.2 + 0.6 * 0.4)}{(0.8 - 0.4)} = 12.96 = 13$$

With the minimum required sample size calculated above, the occurring error is 5% with the 95%confidence interval. In order to decrease the error interval, the same calculation completed above is repeated with 99% confidence interval. The parameters of equation 5.3-1 introduced above are going to keep the same value except for Z_α = and Z_β. With α=0.01, Z_α =2.58 and Z_β =2.33 from table 5.3.1.

$$n = \frac{(2.58 + 2.33)^2 (0.8 * 0.2 + 0.6 * 0.4)}{(0.8 - 0.4)} = 24.18 = 25$$

From the above equation the minimum required sample size consists of 25 subjects to obtain a 99% confidence interval However, to reduce further the error interval, we are going to recruit 40 individuals for each 2 sub-scenario.

Table 5.3.1: Standard Normal Deviates α and ß

Table of standard normal deviates for Z_{α}		Table of standard normal deviates for Z_{β}		
False-change (Type I) error rate (α)	Z_{α}	Missed-change (Type II) error rate (ß)	Power	Z_{β}
0.40	0.84	0.40	0.60	0.25
0.20	1.28	0.20	0.80	0.84
0.10	1.64	0.10	0.90	1.28
0.05	1.96	0.05	0.95	1.64
0.01	2.58	0.01	0.99	2.33

In order to make the selected subjects closely duplicate the actual Florida drivers population, and since it is very hard to estimate the age and gender percentage on the roads, the distribution of the age and gender of the subjects were borrowed from the Florida crash database where males represent 60% versus females 40%, and middle age represent 60% versus young 40 % of the population. It is assumed that the young age group varies between the ages of 18 and 25 and the middle age group varies between 25 and 55. Table 5.3.2 below represents the final gender and age breakdown of the subjects that completed the experiment.

5.4 Subjects distribution for groups A, B, and C

As shown in table 5.4.1, groups A, B, and C consisted of 20 subjects each. Table 5.4.1 also shows the age and gender distribution of each group and the sub-scenarios driven by each group.

Table 5.4.1: Group A, B, and C distributions

GROUP	AGE	MALE	FEMALE	TOTAL	SUB-SCENARIO DRIVEN PER GROUP
GROUP A	YOUNG	5	3	20	SIM-PC FROM HVBS
	MIDDLE AGE	7	5		SIM-LSV FROM VVBS
GROUP B	YOUNG	5	3	20	SIM-PC FROM VVBS
	MIDDLE AGE	7	5		SIM-LTV FROM HVBS
GROUP C	YOUNG	5	3	20	ADDITIONAL TRAFFIC LIGHT
	MIDDLE AGE	7	5		

HVBS= Horizontal View Blockage Scenario
VVBS= Vertical View Blockage Scenario

CHAPTER 6: ANALYSES OF EXPERIMENT DATA OUTPUT

6.1 Data collection

The data collector records vehicles data of all significant vehicles in the system every 1/30-second, including vehicle position (X and Y coordinates), speed, acceleration input, braking input, and steering input. The following paragraphs will explain thoroughly the collected raw data and the derived data from the raw data.

6.1.1 Simulator Vehicle speed

During the course of the experiment, the speeds of the simulator car and all significant vehicles are recorded at 1/30-second time interval, as shown as Figure 6.1.1.1. As shown the variation of the simulator speed varies according to the drivers the needs to speed, brake, and stop. The x-axis in Figure 6.1.1.1 is the time in second, the time starts when the simulator engine starts and ends when the simulator engine is turned off. Therefore, from the same graph one can see that the duration of this experiment is approximately 2 minutes which might vary between drivers.

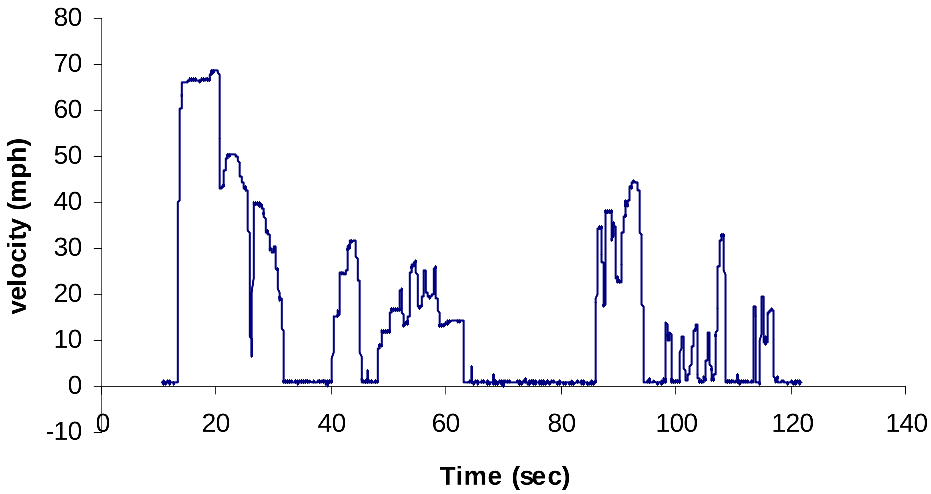

Figure 6.1.1.1: Typical speed distribution of simulator vehicle during LTV experiment

6.1.2 Acceleration and brake input

The Acceleration and brake input are recorded in percentage as a percentage of the current position of the brake and gas pedals position relatively to their maximum position. Figure 6.1.2.1, from the horizontal visibility scenario, shows the variation of the brake pedal position during the course of the experiment. Whenever the brake input is 100%, the deceleration rate is maximal. Therefore, from the same Figure one can see that at the end of the experiment when the drivers brakes the deceleration input is maximal and its slope is very steep which suggests a sudden braking.

Figure 6.1.2.2 shows the variation of acceleration input during the course of the experiments for a typical subject. This Figure also reveals the behavior of the drivers. If the drivers acceleration input is large it is concluded that the driver is an aggressive driver. However, from the same Figure, the acceleration input was less than 40% at all times which means that this particular driver was a typical calm driver aggressive.

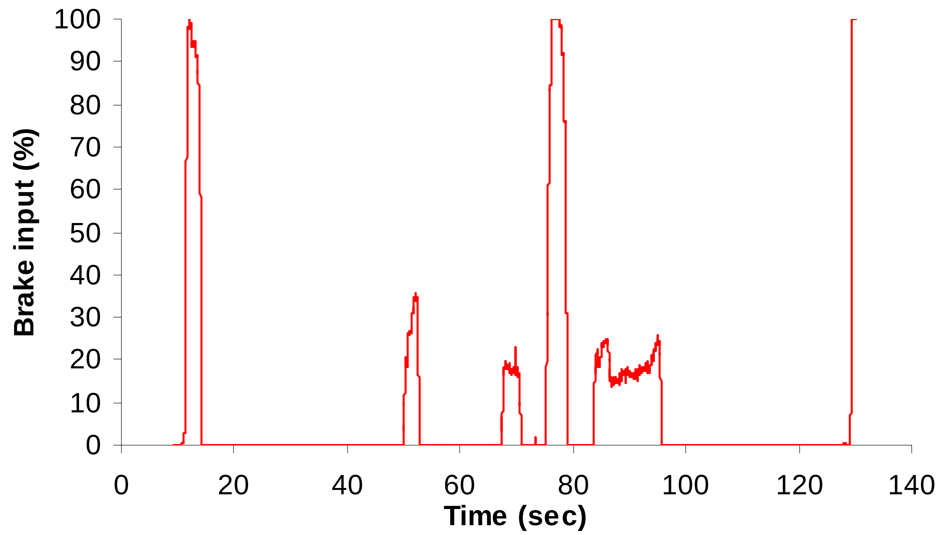

Figure 6.1.2.1: Brake input of a typical subject during LTV experiment

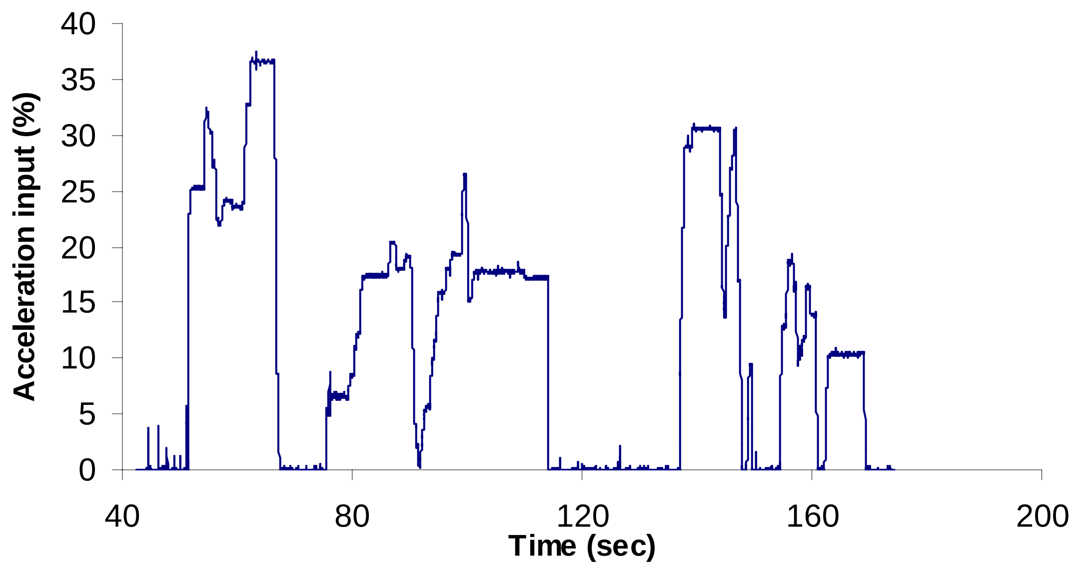

Figure 6.1.2.2: Acceleration input of a typical subject during LTV experiment

6.1.3 Steer control

The steering output data display the current angle of the simulator's steering wheel during the experiment. The steering input is also recorded at every 1/30 seconds. Figure 6.1.3.1 shows the steering input during the vertical visibility experiment. When the values of the steering angle in radians approaches zero, it means that the subject is driving straight. The crest curves (positive and negative) in the Figure 6.1.3.1 means that the driver is turning the steering wheel to make a left or a right turn.

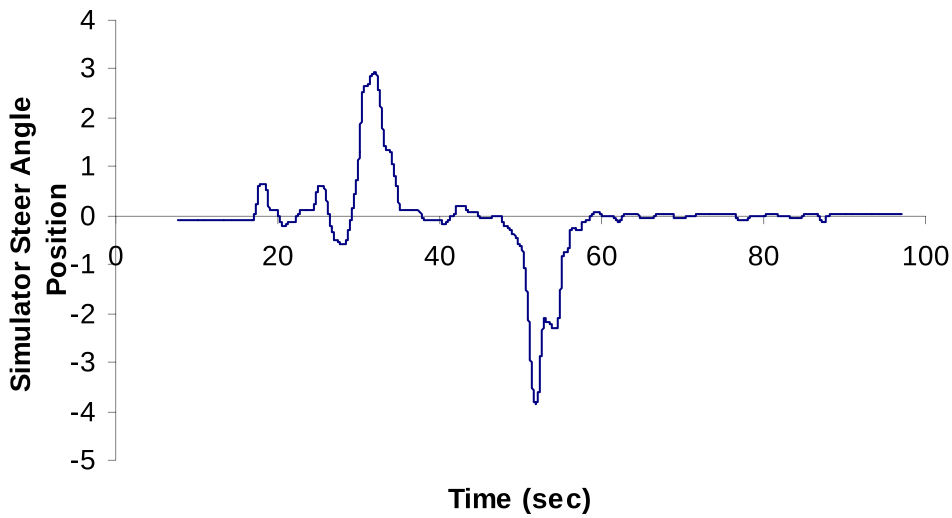

Figure 6.1.3.1: Steering behavior record of subjects during left turn maneuver

The recorded data track the movements and the behavior of all vehicles in the simulation system accurately. In all conducted experiments, data collection began when the simulator car's engine was started and stopped when the simulator's engine was turned off. The data output was saved in a text file. Each line in the output file represents data recorded at a 30 Hz rate as shown in table B1 and B2 in appendix B.

During the experiment, the number of crashes (if any) was noted by one of the researchers located in the simulator observation room and was checked by a code written in Visual Basic C language as shown in appendix A.

6.2 Experiment variables

The above collected data are the general variables called raw data. From the raw data, some significant variables are derived.

6.2.1 Horizontal visibility blockage

As explained before, the horizontal visibility blockage experiment consists of 2 sub-scenarios; simulator car following a passenger car sub-scenario, and simulator car following LTV sub-scenario. In this section, a thorough explanation of the derived data for the horizontal visibility blockage scenario, shown in appendix C, will be conducted.

6.2.1.1 Deceleration rate.

The deceleration rate of the simulator is one of the important variables for the analysis. The deceleration rate is recorded at the end of the experiment when the vehicle from the opposing traffic makes a sudden left turn and the leading vehicle brakes suddenly which leads the simulator car to decelerate. The deceleration rate is the initial velocity at the instant the simulator starts braking minus the final velocity over the time it took the simulator car to come to a complete stop.

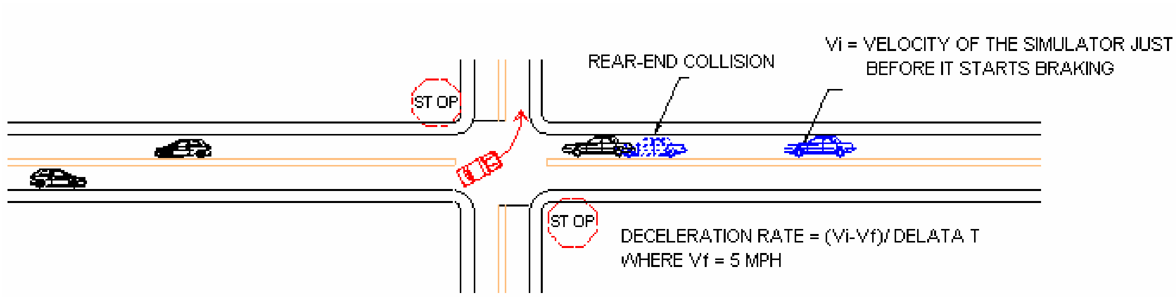

Figure 6.2.1.1.1: Deceleration rate illustration

The final velocity Vf is assumed to be 5 mph since in some cases when the vehicles have enough time to brake and stop, they start braking when they are far and they roll at approximately 5mph or less for a while before they come to a complete stop. Therefore, when we calculated the deceleration rates, to avoid the rolling period which might alter the real deceleration rate, a final velocity of 5 mph was assumed and applied.

6.2.1.2 Response delay time

The response delay time is one of the important derived variables for the analysis. Usually, the response delay time is obtained by subtracting the difference in time between the time when the leading car starts braking and the time the simulator car starts braking. However, in the SIM-PC sub-scenario the response delay time could not be obtained by the method mentioned before. Indeed, the simulator car following the passenger car might react to the car making a left turn instead of reacting to the lead vehicle brake lights since the driver can see that vehicle. For consistency reasons between the two sub-scenarios response delay time calculation, it is assumed that the response delay time is the difference in time between the time the vehicle from the opposing traffic makes a left turn and the instant the simulator car starts braking. This assumption is used for both sub-scenarios of the horizontal visibility blockage scenarios. Figure 6.2.1.2.1 illustrates the response delay time calculation.

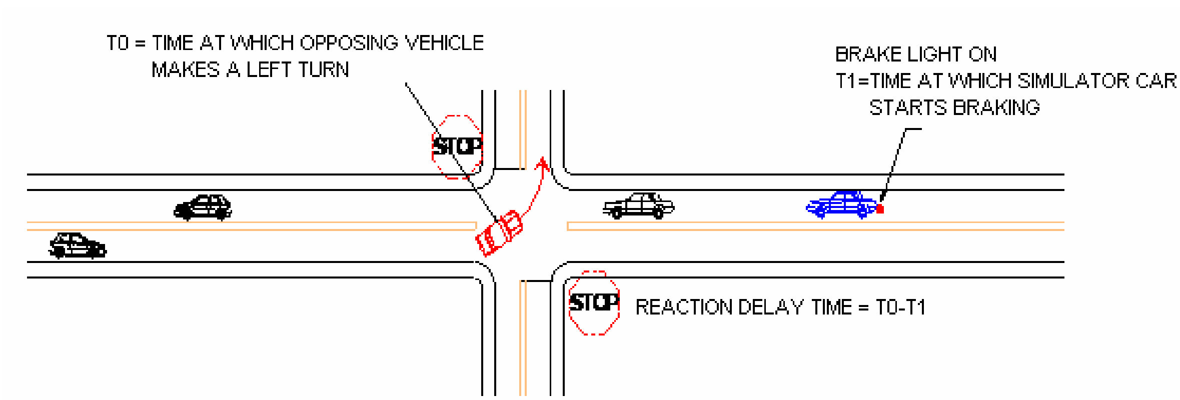

Figure 6.2.1.2.1: Response delay time calculation

6.2.1.3 Cruising velocity

The cruising velocity of the simulator car is also one of the important variables of the analysis. The cruising velocity of the simulator is the average velocity at which the simulator was driving during the course of the experiment in mph. Therefore, the captured cruising velocity is the velocity just before the simulator car starts braking.

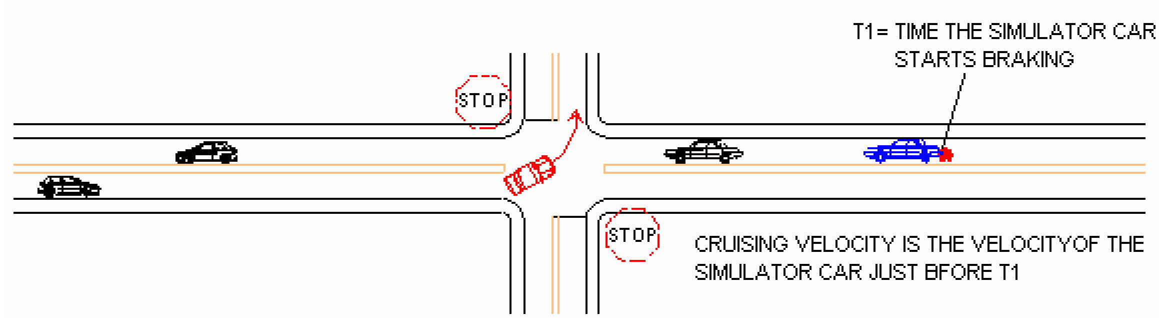

Figure 6.2.1.3.1: Cruising velocity illustration

6.2.1.4 Gap between the two vehicles

The Gap is the distance in feet between the following and the leading vehicles. The simulator system records X-Y position of the center of the vehicles. Therefore, the gap is the gap between the two centers of the vehicles. The gap is the average gap the simulator driver kept between him and the leading car. However, for the analysis, the gap is the gap between the two vehicles just before the simulator car started braking. Figure 6.2.1.4.1 illustrates the gap calculation method.

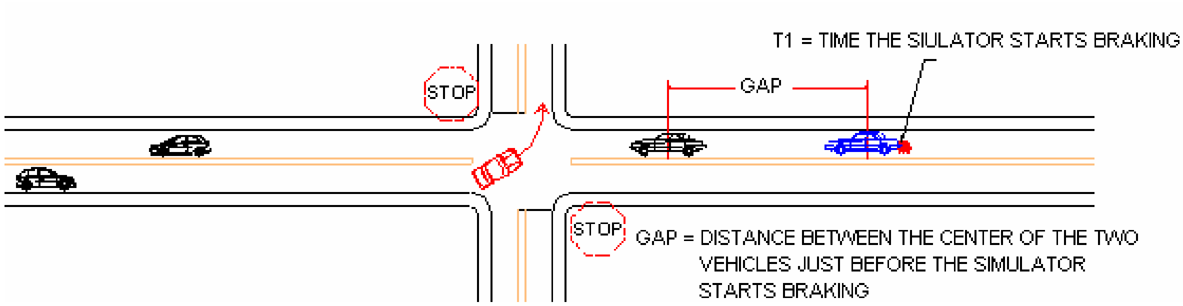

Figure 6.2.1.4.1: Gap calculation method

6.2.1.5 Angular velocity of the simulator car

The angular velocity is also one of the factors that indicate a collision threat. Indeed, some drivers acquire higher driving skills than others, and they might be able to shift the steering wheel and rotate the car to escape the accident. Therefore, this threat should be accounted for in the analysis to stress on the risk of driving behind an LTV. The angular velocity of the simulator car is the velocity at which the simulator car shifted with an angle from the moment it started braking until it came to a complete stop. The angular velocity is calculated with the following equations:

$$\alpha = \tan^{-1}\left(\frac{Y_f - Y_i}{X_f - X_i}\right) \qquad (6.2.1.5.1)$$

Where:

X_f and X_i : are the final and initial x positions of the center of the simulator car.

Y_f and Y_i: are the final and initial y positions of the center of the simulator car.

α= The angle at which the simulator shifts from its initial position in degrees/sec

$$AngularVelocity = \frac{\alpha}{\Delta t} \qquad (6.2.5.1.2)$$

Where:

Δt = The time difference between the time the simulator car starts decelerating and the time it stops.

Figure 6.2.1.5.1 below illustrates the angular velocity calculation method.

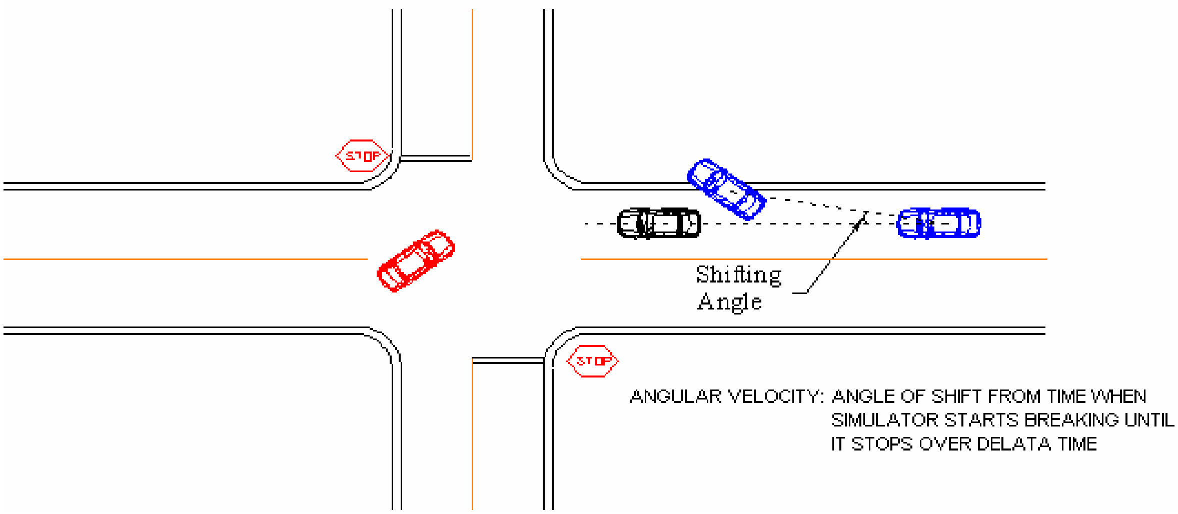

Figure 6.2.1.5.1: Angular velocity calculation method.

6.2.2 Vertical visibility blockage

As explained before, the vertical visibility blockage experiment consists of 3 sub-scenarios; simulator car following a passenger car sub-scenario, simulator car following a school bus sub-scenario, and simulator car following a school bus with an addition of a traffic signal pole on the right side of the road sub-scenario. In this section, a thorough explanation of the derived data, shown in appendix C for the vertical visibility blockage is conducted.

6.2.2.1 Cruising velocity of the simulator car

The cruising velocity of the simulator car is the average velocity at which the simulator car was driving throughout the course of the three sub-scenarios in mph. Therefore, the captured velocity is the velocity of the simulator car just before the traffic signal turns amber. Figure 6.2.2.1.1 illustrates the velocity calculation method.

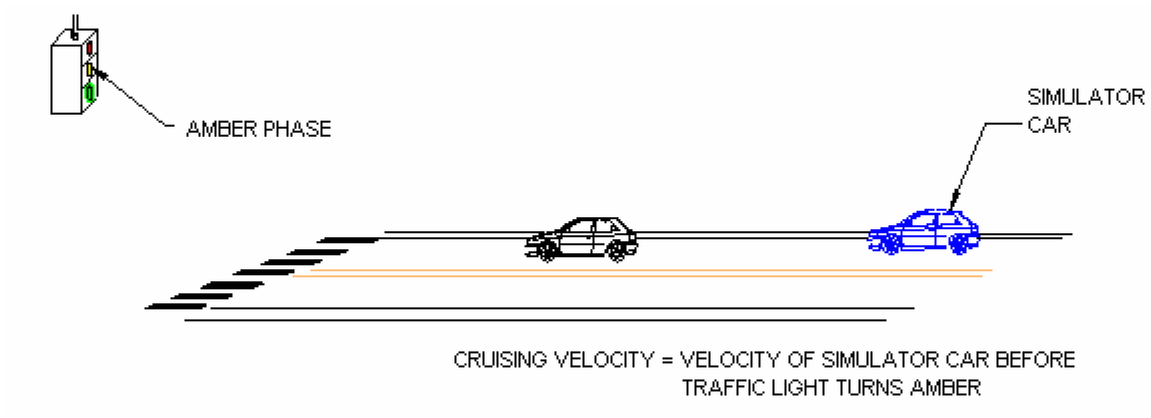

Figure 6.2.2.1.1 Cruising velocity calculation method

6.2.2.2 Deceleration rate of the simulator car

The deceleration rate is one of the important variables for the vertical visibility analysis. Indeed, when the simulator car follows a school bus, the subjects might be able to see the traffic light and manage to stop safely at high deceleration rate. Therefore, this deceleration rate must be taken into consideration since it also reveals the potential danger of running the red light. The deceleration rate is the velocity difference between the time the simulator car starts braking and the time it comes to a complete stop divided by the time difference. Figure 6.2.2.2.1 illustrates the deceleration rate calculation method.

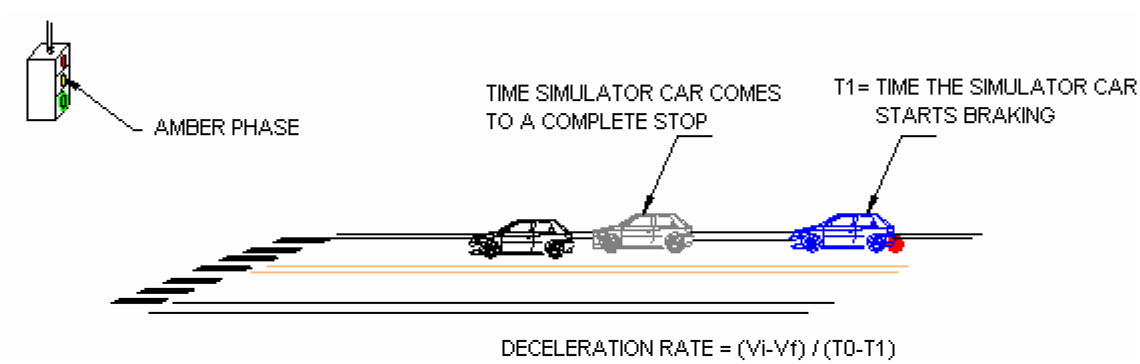

Figure 6.2.2.2.1: Deceleration rate calculation method

6.2.2.3 Response delay time

The response delay time is the time it took the simulator car driver to react to the traffic signal change from green to amber plus the delay time. The delay time is the time it took the simulator driver to see the traffic signal. In the SIM-PC sub-scenario it is expected that the delay time is zero. However, the delay time for simulator car following a school bus is the time delay it took the simulator car driver to see the traffic signal. Moreover, if the simulator car runs the red light, the delay time is very close to the time it takes the passenger car to cross the intersection since the traffic signal turned amber, which means that the driver saw the traffic signal but it was too late to stop, or the delay time is larger than the time it takes the simulator car to cross the intersection which means that the driver did not see the traffic signal at all. In both cases the response delay time would be null. Figure 6.2.2.3.1 illustrates the method for calculating the response delay time.

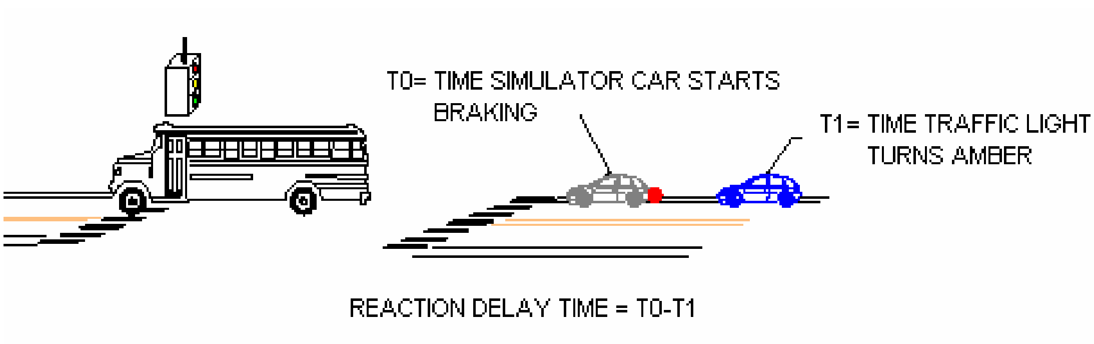

Figure 6.2.2.3.1: Response delay time calculation method

6.2.2.4 Red light running rate

The red light running rate is one of the most important variables in studying vertical visibility blockage. From the coordinates of the simulator scenario, the vehicles were driving in the opposite direction of the y-axis, and the y coordinate of the intersection leg limit is 10,590 as shown in Figure 6.2.2.4.1. Therefore, if the driver’s data y-coordinate at the end each sub-scenario is less than 10,590 (the intersection leg limit) it means that the simulator crossed and ran the red light, moreover, if the y-coordinate is between 10,590 and 10,550, it means that the subject stopped in the middle of the intersection.

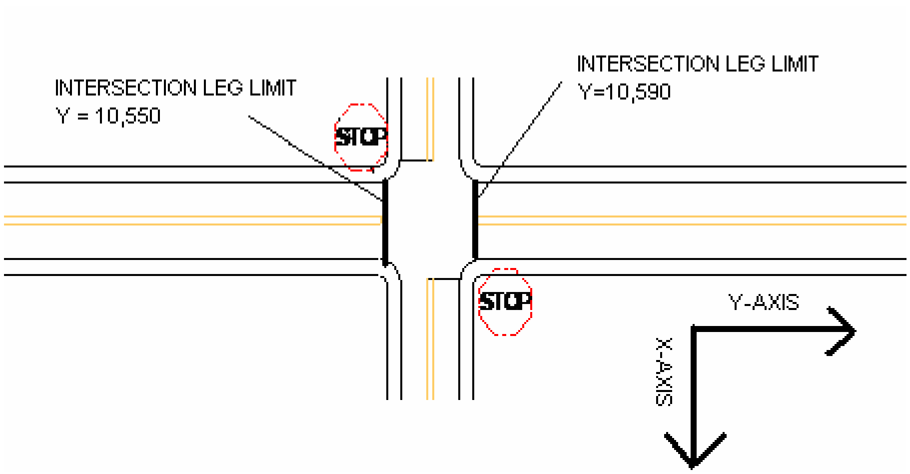

Figure 6.2.2.4.1: Red light running rate calculation

6.3 Program for calculation of experiment variables

The "raw" data output consists of tens of thousands of lines for each subject as shown in appendix B, therefore a code was written in C Visual Basic, as shown in appendix A, to calculate the variables for each subject in the experiment.

CHAPTER 7: HORIZONTAL VISIBILITY SCENARIO VARIABLES ANALYSIS

7.1 Operating cruising velocity of the Simulator

The cruising velocities of the simulator car following PC and following LTV versus the 35 mph speed limit, as shown in Figure 7.1.1, show that the drivers were following the speed limit which suggests that they drove the simulator car as they drive their own vehicles in real life.

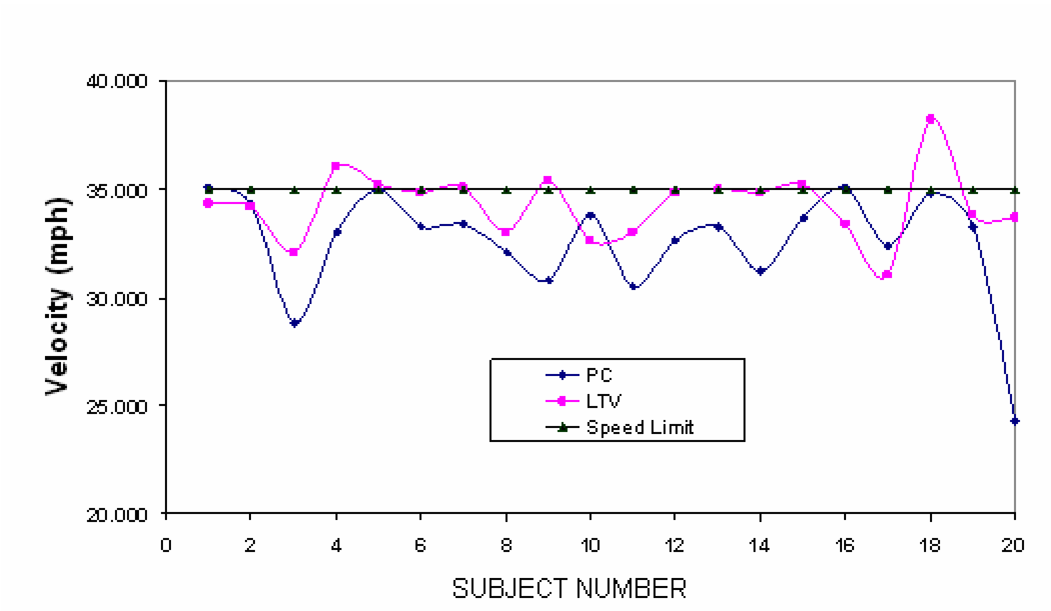

Figure 7.1.1: Cruising velocity of the simulator car

7.2 Rear-end collisions for following an LTV and following a PC

From the collected data, 2 subjects out of 20 subjects driving the simulator behind the PC were involved in a rear-end collision with the PC. However, 8 subjects out of the 20 subjects driving the simulator car behind an LTV got in a rear-end collision with the LTV. Therefore, the probability of being involved in an accident following PC:

$p = \frac{2}{20} = 0.1 = 10\%$, and the probability of getting in an accident following LTV**:**

$p = \frac{8}{20} = 0.4 = 40\%$.

To determine whether there is a significant statistical difference between the two ratios a chi-square test was completed.

Table 7.2.1 below is the output from MINITAB for the chi-square test with 95 % confidence interval. The resulting P-value is equal to 0.013 which is less than α=0.05. As a conclusion, there is a significant statistical difference between the accident ratios for following an LTV and following a PC with the accident ratio for following an LTV higher than the accident ratio following a PC.

Table 7.2.1 MINITAB output: Chi-Square test for accident ratios

```
CHI-SQUARE TEST FOR C1 AND C2

EXPECTED COUNTS ARE PRINTED BELOW OBSERVED COUNTS
CHI-SQUARE CONTRIBUTIONS ARE PRINTED BELOW EXPECTED COUNTS

          C1      C2  TOTAL
    1     18       2     20
       14.50    5.50
       0.845   2.227

    2     11       9     20
       14.50    5.50
       0.845   2.22
TOTAL     29      11     40

CHI-SQ = 6.144, DF = 1, P-VALUE = 0.013
```

7.3 Deceleration rates for following a PC and following an LTV

The deceleration rate is an important indication of accidents risk. If the deceleration rate of the simulator car is high, it means that there is a potential for rear-end collision with the leading vehicle and that there is a potential rear-end collision with a possible vehicle following the simulator car. Therefore, if the deceleration rate of the simulator car following an LTV is higher than deceleration rate of the simulator following a PC, one can conclude that driving behind an LTV produces a higher potential of rear-end collision with the leading. Figure 7.3.1 below shows the deceleration rates in ft/sec/sec of the simulator car for both sub-scenarios, with the deceleration rate for following an LTV higher than the deceleration rate for following a PC.

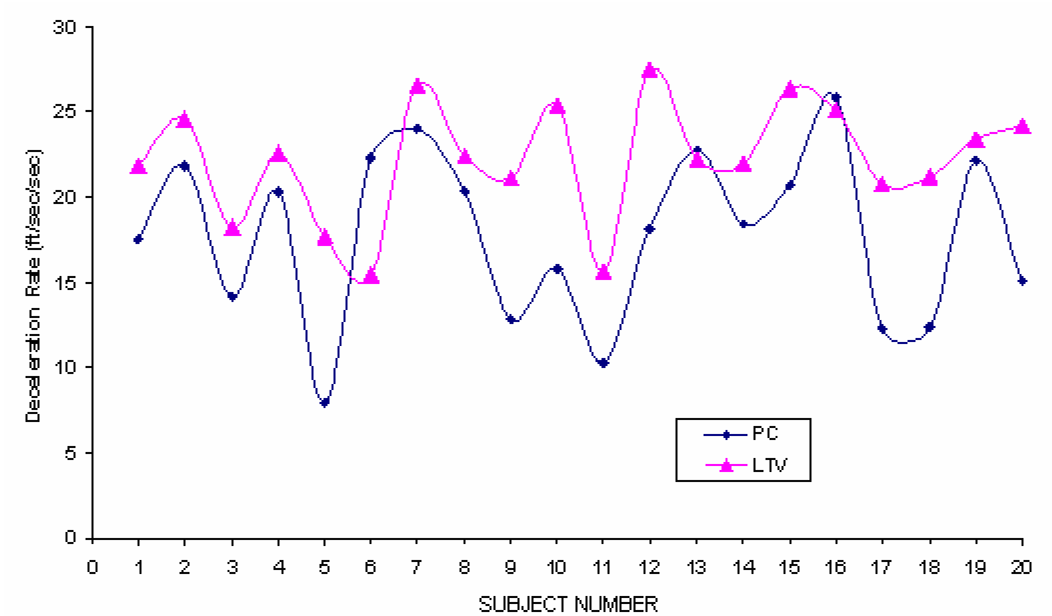

Figure 7.3.1: Deceleration rates for following a PC and following an LTV

A 2 sample t-test was computed in MINITAB to check for a statistical significant difference between the means of both samples with the following null and alternative hypotheses:

$$Ho: \mu_{ltv} = \mu_{pc}$$
$$H1: \mu_{ltv} \neq \mu_{pc}$$

From the MINITAB output below the p-value is equal to 0.002 which means that there is a statistical significant difference between the deceleration means of following a PC and following an LTV. The deceleration mean for following an LTV is equal to 22.23 ft/sec/sec and the deceleration mean for following a PC is equal to 17.77 ft/sec/sec.

Table 7.3.2: MINITAB output for deceleration rates t-test

TWO-SAMPLE T-TEST AND CI: C1, C2

```
TWO-SAMPLE T FOR C1 VS C2

     N   MEAN  STDEV  SE MEAN
PC  20  17.77   4.96      1.1
LTV 20  22.23   3.43     0.77


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  -4.46206
95% CI FOR DIFFERENCE:  (-7.20335, -1.72078)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -3.31  P-VALUE = 0.002  DF = 33
```

7.4 Gap test for following a PC and LTV

Gap is also one of the important variables in our research. For example, if the gap of following a vehicle is smaller than the gap of following another vehicle, the vehicle followed with the smaller gap is more likely to be involved in an accident. From Figure 7.4.1 below, the gap for following a PC looks larger than the gap for following an LTV. Therefore, it is suggested following an LTV has a higher potential of rear-end collision with the leading vehicle.

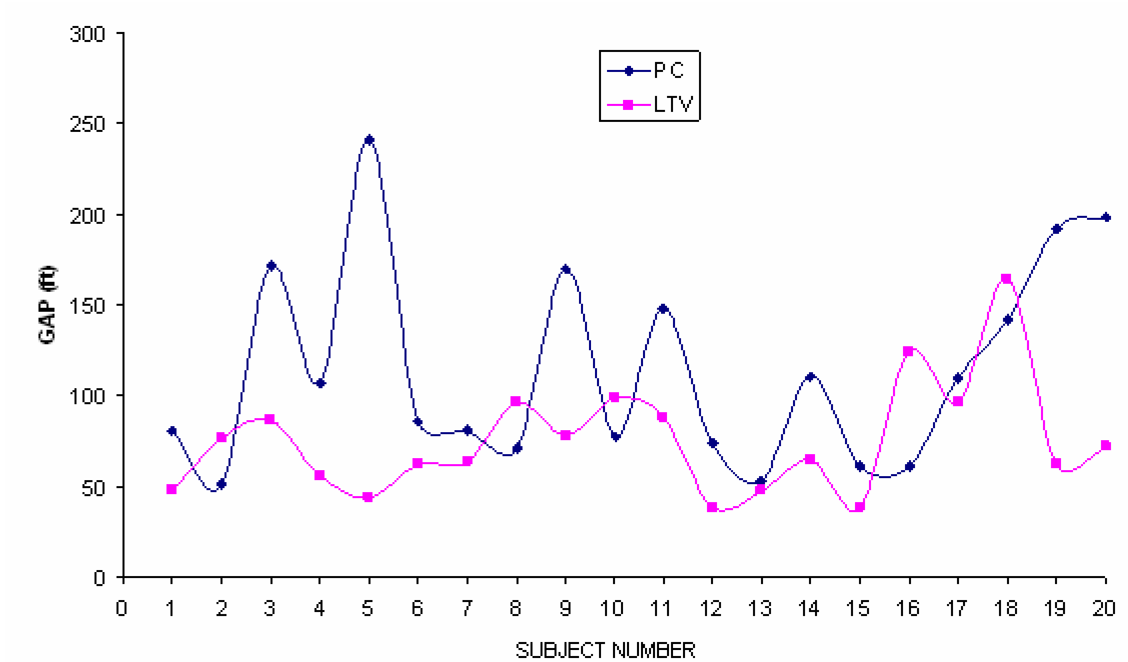

Figure 7.4.1: Gap for following a PC and LTV

A 2 sample t-test was performed to compare the gap means of both sub-scenarios with a 95% confidence interval. From the MINITAB output in table 7.4.2, the resulting p-value is 0.01 which is smaller than 0.05. Therefore, there is a statistical difference between the gap means of both sub-scenarios with the mean gap of following an LTV equal to 75.6 ft and the mean of following a PC equal to 114.6 ft.

The subjects drove closer to an LTV than to a passenger car because when they drive behind an LTV they feel uncomfortable and anxious to pass it due to the visibility blockage the latter causes, which is supported by the findings from Sayer (2003).

Table 7.6.2: MINITAB output for 2 sample t-test, following an LTV and PC

TWO-SAMPLE T-TEST AND CI: C1, C2

```
TWO-SAMPLE T FOR PC VS LTV

     N   MEAN  STDEV  SE MEAN
PC  20  114.6   55.6       12
LTV  20   75.6   31.0      6.9


DIFFERENCE = MU (PC) - MU (LTV)
ESTIMATE FOR DIFFERENCE:  39.0721
95% CI FOR DIFFERENCE:  (9.9469, 68.1973)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = 2.74  P-VALUE = 0.010  DF = 29
```

7.5 Response delay time for following a PC and following an LTV

The response delay time is a tool to test the view blockage the LTV causes. Indeed, if the response delay time when following an LTV is higher than the response delay time when following a passenger car, it means that it took the subject driving behind the LTV a longer time to see and react to a hazard, which is caused by a visibility blockage problems. In the horizontal visibility blockage scenario, the higher ratio of rear-end collisions for following and LTV is suggested to be linked to a visibility blockage problem caused by the LTV. Figure 7.5.1 shows the response times for both following a PC and following an LTV sub-scenarios.

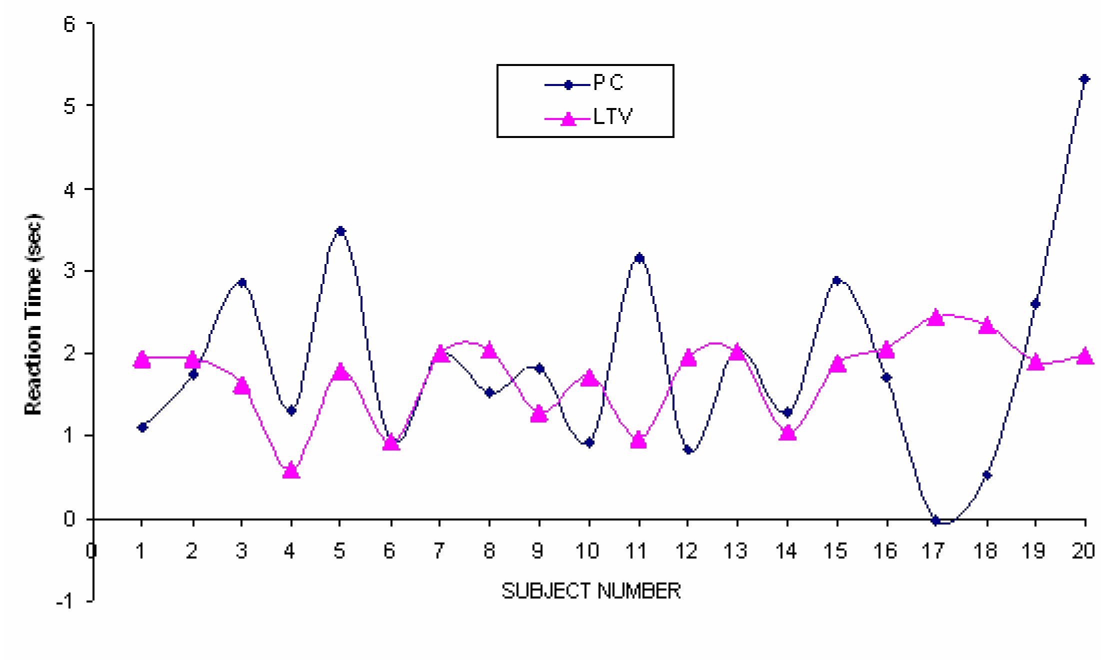

Figure 7.5.1: Response delay time for following an LTV and following a PC

From Figure 7.5.1, the response delay time for following a PC is higher than response delay time for following an LTV in some cases. This can be explained by the fact that when the gap is relatively very large, the derived response delay time is not actually the response delay time, but it is the response delay and decision braking time. Therefore, when a subject is driving at a large gap from the PC, he might see the opposing vehicle making a left turn but he won't brake until he gets close to the leading PC. The time it took the driver to get close and brake is called decision braking time. For instance, from Figure 7.4.1, subject number 20 was driving at 199ft behind the PC which resulted in a response time of 5.33 seconds and subject number 5 was driving at 242 ft from the leading vehicle which led to a response time of 3.47 sec.

A 2 sample t-test was computed to compare the means of response delay time of both sub-scenarios and the resulting P-value of 0.551 is greater than 0.05 which means that there is no significant statistical difference between the response delay time means of the two samples.

7.6 Cruising Velocity means for following a PC and following an LTV

The velocity is another important variable in studying the horizontal visibility blockage scenario. For instance, if the simulator car driver drives behind an LTV at a relatively higher velocity than he drives behind a passenger car, it is suggested that driving behind an LTV produces a higher potential of rear-end collision. From Figure 7.6.1 below, one can see that the cruising velocities behind an LTV are higher than the velocities behind PC.

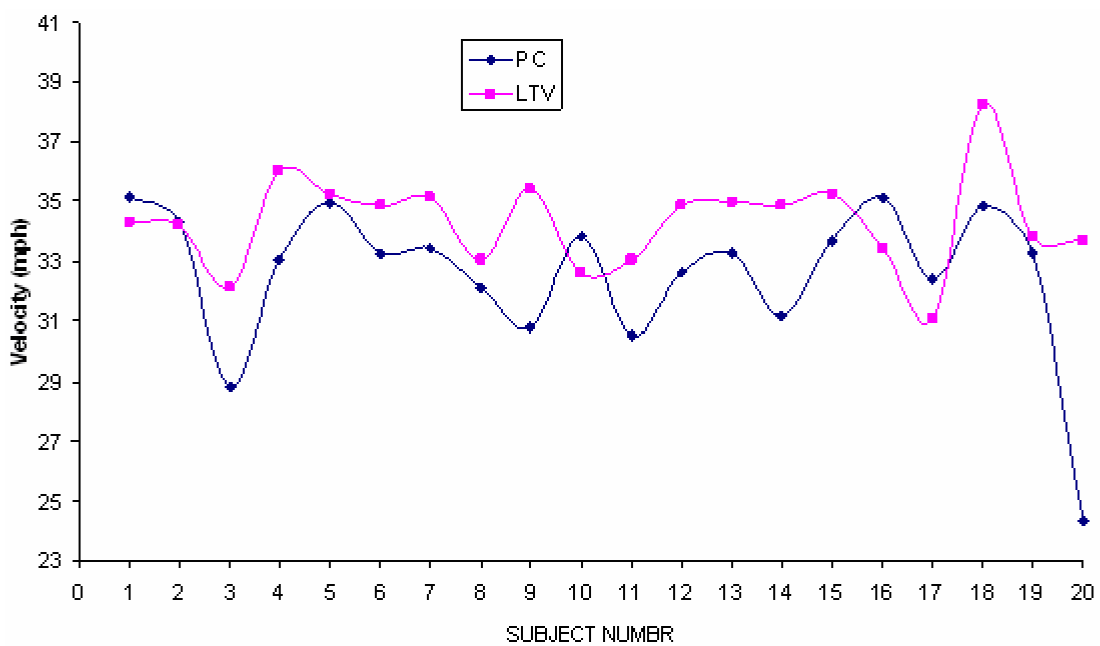

Figure 7.6.1: Cruising velocity for following a PC and LTV

A 2 sample t-test was computed to compare the means of the two samples for a 95 % confidence interval with the following hypotheses:

$$Ho: \mu_{ltv} = \mu_{pc}$$
$$H1: \mu_{ltv} \neq \mu_{pc}$$

From the MINITAB output below, the P-value is 0.013 which is less than 0.05. Therefore, there is a statistically significant difference between the two sample means with the mean of following an LTV equal to 34.30 mph and the mean of following a PC equal to 32.54 mph. The higher velocity mean for following an LTV can be explained by the fact that subjects driving behind the LTV are uncomfortable and anxious to pass it since they cannot see beyond the latter.

Table 7.6.1: MINITAB output for 2 sample t-test, following an LTV and PC

TWO-SAMPLE T-TEST AND CI: C1, C2

```
TWO-SAMPLE T FOR PC VS LTV

     N   MEAN  STDEV  SE MEAN
PC  20  32.54   2.55     0.57
LTV  20  34.30   1.57     0.35


DIFFERENCE = MU (PC) - MU (LTV)
ESTIMATE FOR DIFFERENCE:  -1.75804
95% CI FOR DIFFERENCE:  (-3.12319, -0.39290)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -2.63  P-VALUE = 0.013  DF = 31
```

7.7 Impact velocity

The impact velocity is velocity at which the simulator car hits the PC or the LTV. The impact velocity shows the severity of the accident. Indeed, if the impact velocity is greater so is the severity of the accident. From Figure 7.7.1 below, the impact velocities with LTV seem to be higher than the impact velocity with PC. The two samples are small and are not valuable to make conclusions. However, they can show a trend of the results. From the trend of the results, one can conclude that not only driving behind an LTV can produce more rear-end collisions than driving behind a passenger car but also that rear-end collisions with LTV are more severe than rear-ends with PC.

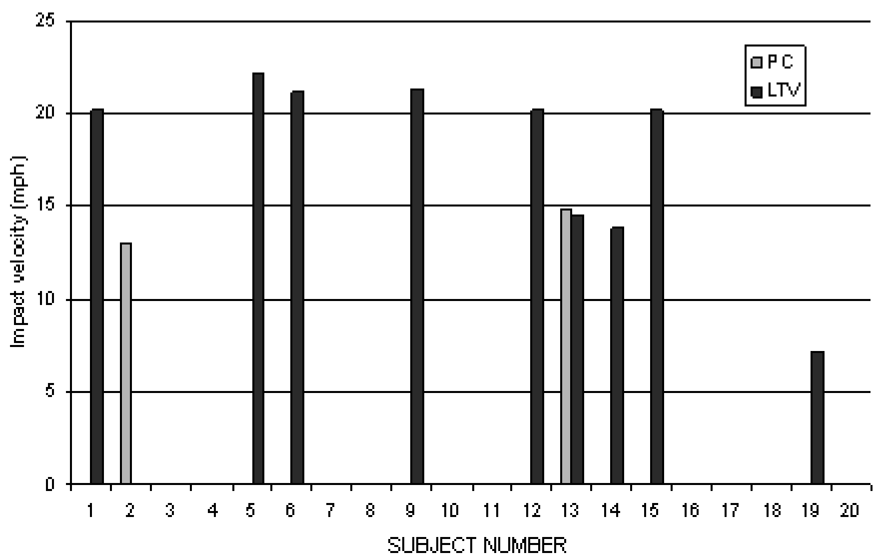

Figure 7.7.1: Impact velocities for following a PC and LTV

7.8 Logistic regression

Logistic regression is a statistical technique for developing predictive models for the probability that an event (such as the rear-end collision) will or will not occur. The probability that a driver will get in a rear-end collision is modeled as logistic distribution in Equation 7.8.1:

$$\pi(x) = \frac{e^{g(x)}}{1 + e^{g(x)}} \tag{7.8.1}$$

The Logit of the multiple logistic regression model is given by Equation 5.8.2:

$$g(x) = \ln\left[\frac{\pi(x)}{1 - \pi(x)}\right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_n x_n \tag{7.8.2}$$

Five potential independent variables, shown in table 7.8.1, suspected to be related to the rear-end collision probability were used to construct the logistic model in SPSS 13.0 statistical software.

Table 7.8.1: Logistic regression independent factors

Variable	**Variable Description**	**Variable Unit**
PCLTV	Following a PC or Following an LTV	0=Following a PC 1=Following an LTV
RT	Response delay time	Continuous (sec)
DR	Deceleration rate	Continuous (ft/sec/sec)
Vel	Cruising velocity	Continuous (mph)
Ratio	(Response delay time(sec))/(Gap(sec))	Dimensionless

A new variable, the ratio of response delay time over gap in seconds, was derived and added to the statistical model independent variables.

The above variables were incorporated in SPSS to create a logistic model. Table 7.8.2 shows the results of the first trial. The independent variables seem to be insignificant for the model with P-values >> 0.05. Even though each variable independently was related to the probability of rear-end collision from the completed t-test, the table below shows that all the variables together are not significant to the model because there is a high correlation between each variable.

Table 7.8.2 SPSS 13.0 output for Logistic regression model

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1(a)	DR	-.129	.119	1.179	1	.277	.879
	RT	1.779	1.448	1.510	1	.219	5.924
	Vel	.289	.294	.966	1	.326	1.335
	Gap	-.034	.028	1.475	1	.225	.967
	Ratio	-1.898	1.743	1.186	1	.276	.150
	pcltv(1)	-1.440	.962	2.238	1	.135	.237
	Constant	-5.415	9.132	.352	1	.553	.004

Ratio1 = (Response delay time/ Gap (sec))

The independent variables with the highest p-value were eliminated one at a time and the observed p-value of each new model was still >> 0.05 which can be explained by the high correlation between the variables. Therefore, there was no good model that combines LTV and PC. A model was created that comprises of LTV and the 5 independent factors and the same procedure was completed in SPSS. After several trials and eliminations, the final model is shown in table 7.8.3 where the p-values< 0.05. The final model consists of one factor which is the ratio of response delay time over gap in seconds.

Table 7.8.3 SPSS 13.0 output for Logistic regression model

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1(a)	ratio1	2.323	1.074	4.674	1	.031	10.202
	Constant	-3.198	1.430	4.999	1	.025	.041

Ratio1 = (Response delay time/ Gap (sec))

$$g(x) = \ln\left[\frac{\pi(x)}{1-\pi(x)}\right] = -3.198 + 2.323x_1$$

From the equation above one can conclude the bigger the ratio of response delay time (in seconds) over gap (in seconds) the larger the probability of rear-end collisions.

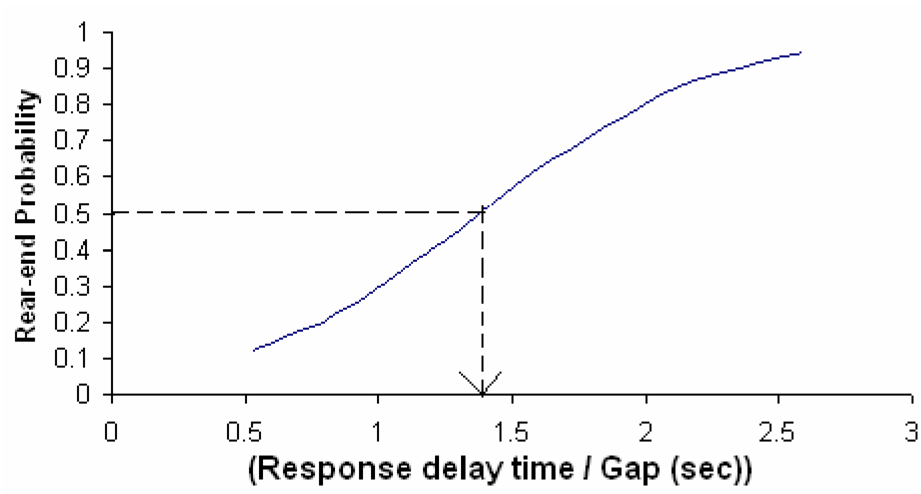

Figure 7.8.4: Rear-end collision probability

The critical ratio (approximately 1.375) can be determined from Figure 7.8.4 as the 50% probability of rear-end collision occurs. It means that the subjects with a ratio of response delay time over gap in seconds equal or greater to 1.375 have at least 50 % or higher chance of being involved in a rear-end collision. And the Graph also shows that the higher the response delay time over gap the higher the probability of getting in a rear-end. Indeed, if the response delay time is 1.375 times greater than the gap in seconds, the subjects are very likely to be involved in a rear-end collision.

7.9 Survey Analysis

As mentioned before, the subjects were asked to take a survey at the end of the experiment. One of the survey questions asked the subjects if they drive closely behind a passenger car or LTV in real life. From group A, which consisted of 20 subjects driving behind a passenger car, 30 % answered that they drive closely to passenger cars in real life and the 70% remaining answered that they don't drive closely to a passenger car in real life. However, from group B, which consisted of 20 subjects, 45% answered that they drive closely to an LTV in real life and 55% answered that they don't drive closely to LTV in real life as shown in Figure 7.9.1.

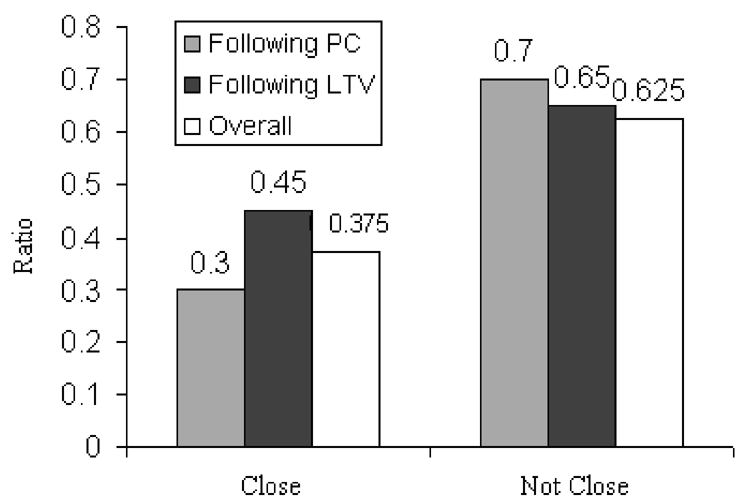

Figure 7.9.1: Driving close to leading vehicle (LTV and PC)

The Subjects from group A and B were asked if they saw the car making a left turn. 50% of the subjects following an LTV answered that they did not see the vehicle from the opposite direction making a left turn and 30 % of the subjects following the passenger car answered that they did not see the vehicle from the opposite direction making a left turn as shown in Figure 7.9.2.

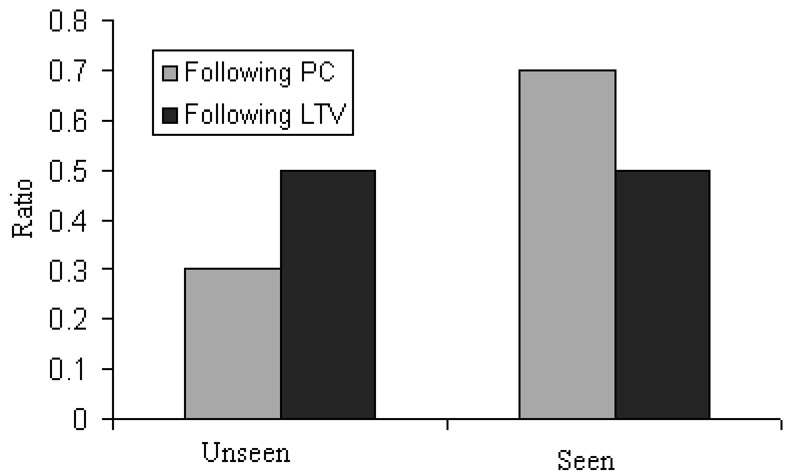

Figure 7.9.2: Seen or Unseen car making a left turn from the opposite direction

The subjects from group B were also asked if they encounter the same visibility problem in real life when the drive behind an LTV in similar circumstances. 65% of the subjects that were said that they encounter similar visibility problem in real life and 35% said that don't encounter similar visibility problems in real life.

7.10 Conclusions

As mentioned before, one of the thesis objectives was to study whether driving behind an LTV increases the probability of rear-end collisions. Therefore, from the conducted analysis it was confirmed that there is a statistically significant difference between the rear-end collisions for following an LTV and following a PC with a higher percentage of rear-ends for following LTVs. Finally, driving a passenger car behind an LTV produces a higher probability of rear-end collisions due to visibility blockage.

Another objective was to study the behavior of the subjects driving behind LTVs and whether that behavior contributed to the increase of rear-end collisions probability. Therefore, from the analysis conducted, the velocities for following an LTV and following a PC were compared and it was confirmed that there is a statistically significant difference between the velocity means with a higher mean for following LTVs. Then, one can relate the speeding behavior to the fact that subjects drive uncomfortably behind an LTV because they cannot see beyond it, therefore they feel the urge to pass it. This behavior contributes to the rear-end probability increase for following an LTV. The gaps for following an LTV and following a PC were compared and it was confirmed that there is a statistically significant difference between the means of the gap of both samples with the mean gap for following an LTV smaller than the mean gap for following a PC. This behavior can be explained by the same reasons that the drivers drive uncomfortably behind LTVs because they cannot see beyond them. Therefore, subjects speed and stay close behind LTVs waiting for a chance to pass them. Finally one can conclude that the probability of rear-end collisions for driving behind an LTV is higher than the probability of rear-end collision for driving behind a PC due to visibility blockage that obstructed the visibility of the hazard and due to the driver behavior caused by the visibility blockage.

CHAPTER 8: VERTICAL VISIBILITY DATA ANALYSIS

8.1 Vertical visibility blockage problem

This part of the thesis will focus on comparing analyzing the simulator following a passenger car sub-scenario and simulator following a school bus (LSV) sub-scenario.

8.1.1 Operating cruising velocity of the Simulator

The cruising velocities of the simulator car following the passenger car and the school bus versus the speed limit, 35 mph, are shown in the Figure 8.1.1.1 below. The majority of the cruising velocities appear to close to the speed limit. Therefore, these velocities seem realistic and reflect the same velocities driving would follow on the roads.

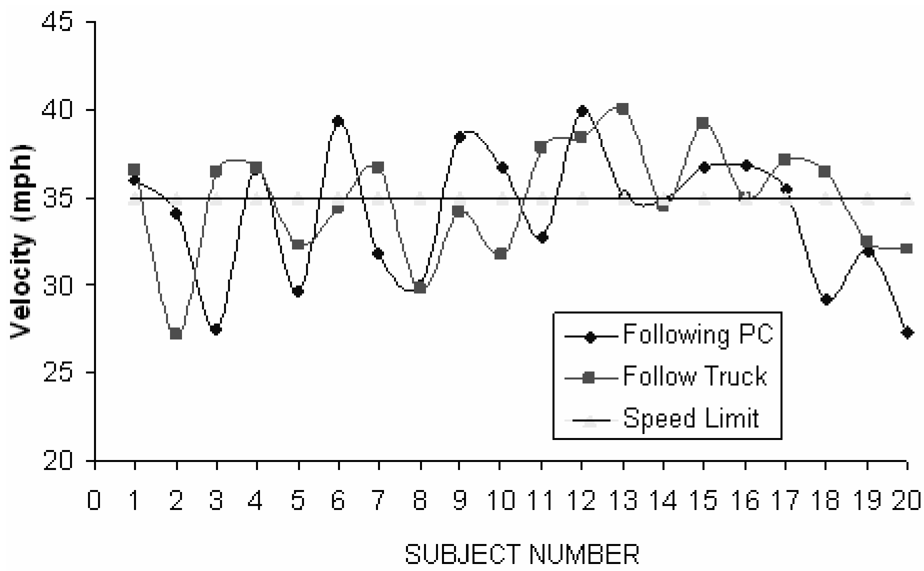

Figure 8.1.1.1: Velocities of following a school bus and a PC

8.1.2 Chi-square Test for Statistically significant difference between red light running between following a PC and following a truck

From the collected data, 2 subjects out of 20 subjects driving the simulator behind the PC run the red light. However, 10 subjects out of the 20 subjects driving the simulator car behind truck run the red light. Therefore, the probability of running the red light if following a PC is: $p = \frac{2}{20} = 0.1 = 10\%$, and the probability of running the red light if following a truck**:** $p = \frac{10}{20} = 0.5 = 50\%$.

To determine a significant statistical difference between the two ratios a chi-square test was completed.

Table 8.1.2.1 below is the output from MINITAB for the chi-square test with 95 % confidence interval. The resulting P-value is equal to 0.006 with is less than α=0.05. As a conclusion, there is a significant statistical difference between the red light running ratios for following a PC and following a school bus (or a truck) with red light running ratio higher for following a school bus. As a conclusion, driving behind a school bus or a large truck significantly increases the potential for red light running due to visibility problems.

Table 8.1.2.1: MINITAB output

CHI-SQUARE TEST: C1, C2

```
EXPECTED COUNTS ARE PRINTED BELOW OBSERVED COUNTS
CHI-SQUARE CONTRIBUTIONS ARE PRINTED BELOW EXPECTED COUNTS

          C1      C2  TOTAL
    1      2      18     20
        6.00   14.00
       2.667   1.143

    2     10      10     20
        6.00   14.00
       2.667   1.143

TOTAL     12      28     40

CHI-SQ = 7.619, DF = 1, P-VALUE = 0.006
```

8.1.3 Deceleration Rates Test

In the vertical visibility experiment, the subjects driving the simulator behind the school bus are subject to two alternatives if they see the traffic signal too late or if they don't see it at all: either they run the red light (which includes stopping in the middle of the intersection and clearing the intersection) or brake suddenly and stop on time. For the subjects driving behind the school bus who were able to stop before the intersection, it is expected that their deceleration rates are relatively high since it is assumed that those drivers perceived the traffic signal turning amber later than those driving behind a PC. Therefore, if the subjects driving behind the school bus have higher deceleration rates than those driving behind PC, it is suggested that there was a visibility problem of the traffic signal due to driving behind a larger size vehicle. To test our hypothesis, a 2 sample t-test was completed to compare the means of deceleration rates means of following a school bus and following a PC.

As mentioned before, 20 subjects drove the simulator behind the passenger car and 20 other subjects drove the simulator behind the school bus. However, if the simulator car runs the red light, its deceleration rate would be null since it did not stop. Therefore, the deceleration rates of 10 subjects that did not run the red light when they were driving behind the school bus will be compared to the deceleration rates of the 18 subjects driving behind the PC that did not run the red light.

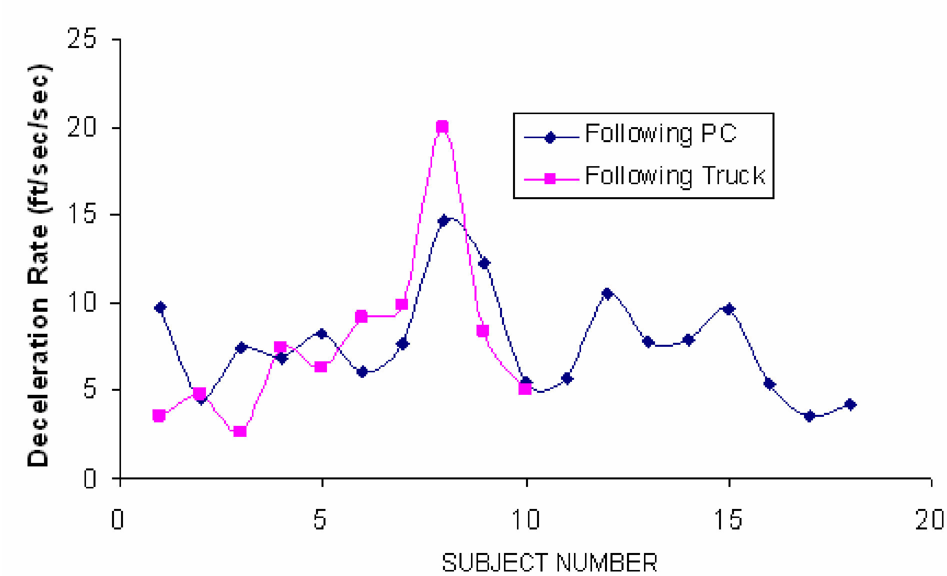

Figure 8.1.3.1: Deceleration rates of simulator for following a school bus and a PC

A 2 sample t-test was computed in MINITAB to check for a statistical significant difference between the means of both samples for 95 % confidence interval with the following hypotheses:

$$Ho: \mu_{truck} = \mu_{pc}$$
$$H1: \mu_{truck} \neq \mu_{pc}$$

From the MINITAB output below the p-value is equal to 0.97 which means that there is no significant statistical difference between the deceleration means of following a PC and following a school bus. The deceleration mean for following a truck is equal to 7.73 ft/sec/sec and the deceleration mean for following a PC is equal to 7.66 ft/sec/sec.

Table 8.1.3.2 MINITAB output

```
TWO-SAMPLE T FOR C1 VS C2

     N  MEAN  STDEV  SE MEAN
C1  18  7.66   2.90     0.68
C2  10  7.73   4.93      1.6


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  -0.065056
95% CI FOR DIFFERENCE:  (-3.773128, 3.643017)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -0.04  P-VALUE = 0.970  DF = 12
```

8.1.4 Response delay time test

The response delay time is the time it took the driver to see and react to the traffic signal phase change. Therefore, when we compare the response delay times of following the school bus and following the passenger car, if the delay response times for following a school bus are greater that those following a passenger car, it is suggested that a visibility problem had occurred. Figure 8.1.4.1 below shows the response times for both scenarios. The response delay times for subjects 3 and 4 following a PC and subject 2 following a school bus are negative which means that the drivers stepped on the brake before the traffic signal turns amber. Those negative values imply that those drivers were cautious and careful when they approached the intersection and decided to slow down.

As mentioned before, 20 subjects drove the simulator behind the passenger car and 20 other subjects drove the simulator behind the school bus. However, if the simulator car runs the red light, its response delay time would be null since it did not stop. Therefore, the response delay time of 10 subjects that did not run the red light when they were driving behind the school bus will be compared to the response delay time of the 18 subjects driving behind the PC that did not run the red light.

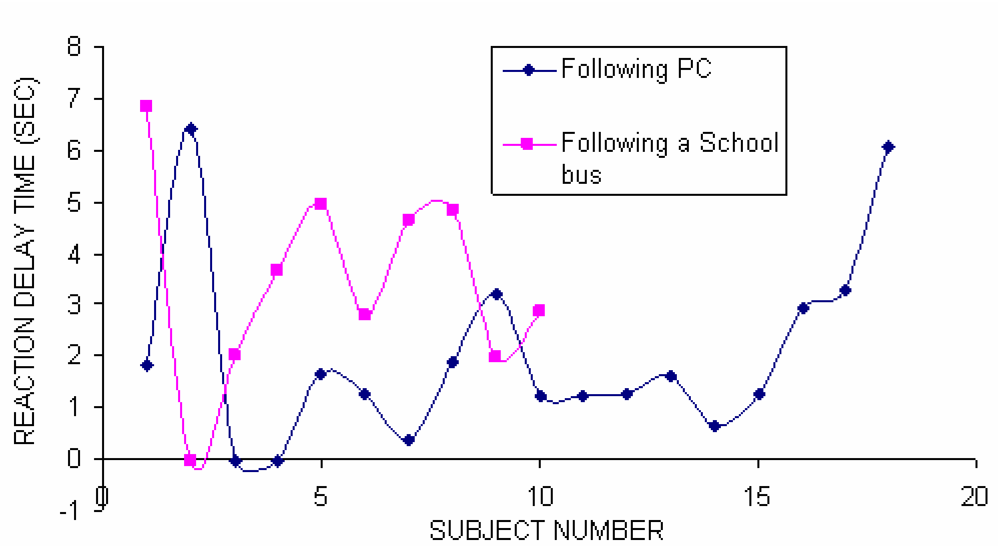

Figure 8.1.4.1- Response delay times of following a school bus and following a PC

As shown in Figure 8.1.4.1 the majority of response delay times of following a school bus are greater than the response delay times of following a PC. From the MINITAB output below the mean response delay time for following a school bus is 3.45 sec and the mean response delay time for following a PC is 2.02 sec.

A 2 sample t-test was computed in MINITAB to check for a statistical significant difference between the means of both samples for 95 % confidence interval with the following hypothesis and null hypotheses:

$$Ho : \mu_{truck} = \mu_{pc}$$
$$H1 : \mu_{truck} \neq \mu_{pc}$$

Table 8.1.4.2 MINITAB output

```
TWO-SAMPLE T FOR C1 VS C2

     N  MEAN  STDEV  SE MEAN
C1  18  2.02   1.81     0.43
C2  10  3.45   1.95     0.62


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  -1.43594
95% CI FOR DIFFERENCE:  (-3.01880, 0.14691)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -1.91  P-VALUE = 0.073  DF = 17
```

From the MINITAB output below the p-value is equal to 0.073 which means that there is no significant statistical difference between the deceleration means of following a PC and following a school bus. However, the p-value is fairly close to 0.05 which means that there is a marginal statistical difference between the response delay times of following a PC and following a school bus with a higher response delay time for following school bus. Therefore, this marginal statistical difference implies a visibility problem for following a school bus that leads to red light running.

8.1.5 Test for cruising velocity

The cruising velocities collected are the average velocities of the simulator car following a PC or a school bus just before the traffic signal turns amber. The purpose of testing the cruising velocities difference between the two scenarios is to study the behavior of subjects driving behind large size vehicles and to analyze the effect of this behavior on the red light running rate. Indeed, if the subjects are frustrated because they are driving blindly behind the bus, they might have higher speeds because of their intent to pass it. From Figure 8.1.5.1 below the velocities seem fairly close. Therefore, one can conclude that the subjects' behavior while driving behind the school bus was similar to their driving behind a passenger car. Furthermore, the velocity does not have a direct impact on the red light running rate. To confirm this conclusion, a 2 sample t-test was completed to compare the velocity means of both samples with the following hypotheses:

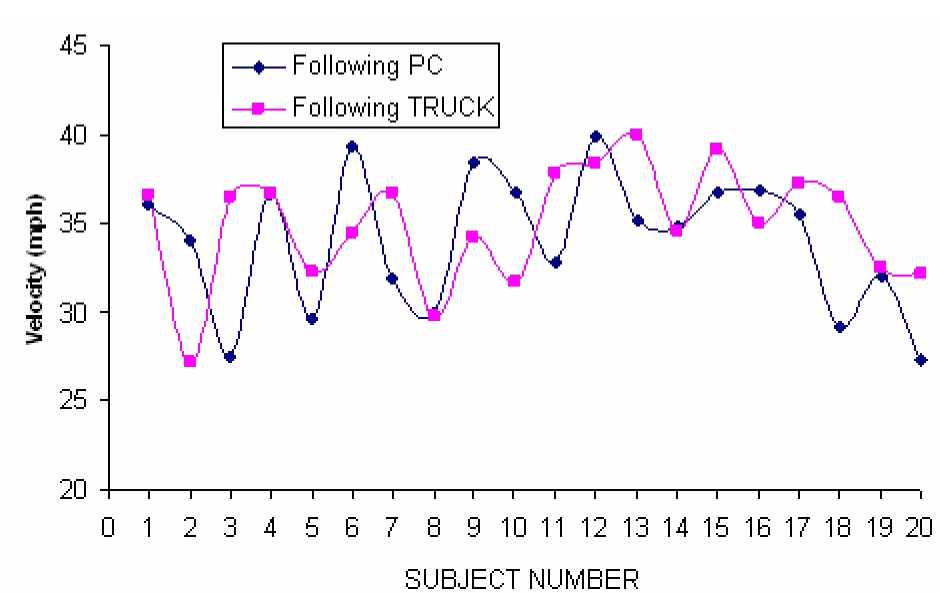

Figure 8.1.5.1: Cruising velocities for following a school bus and PC

$$Ho: \mu_{truck} = \mu_{pc}$$
$$H1: \mu_{truck} \neq \mu_{pc}$$

Table 8.1.5.2: MINITAB output

```
TWO-SAMPLE T FOR C1 VS C2

     N   MEAN  STDEV  SE MEAN
C1  20  34.00   3.80     0.85
C2  20  34.95   3.27     0.73


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  -0.949500
95% CI FOR DIFFERENCE:  (-3.221219, 1.322219)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -0.85  P-VALUE = 0.403  DF = 37
```

From the above MINITAB output the P-value is 0.403 which is greater than 0.05. Therefore there is a no statistically significant difference between the two sample means with the mean of following a school bus equal to 34.95 mph and mean following PC 34.00 mph.

8.1.6 Test for gap

Gap is also one of the important variables in our research. For example, if the gap of following a vehicle is smaller than the gap of following another vehicle, the vehicle followed with the smaller gap is more likely to get in an accident. From Figure 8.1.6.1

below some subjects followed the school bus at a larger gap than the gap for following a passenger car.

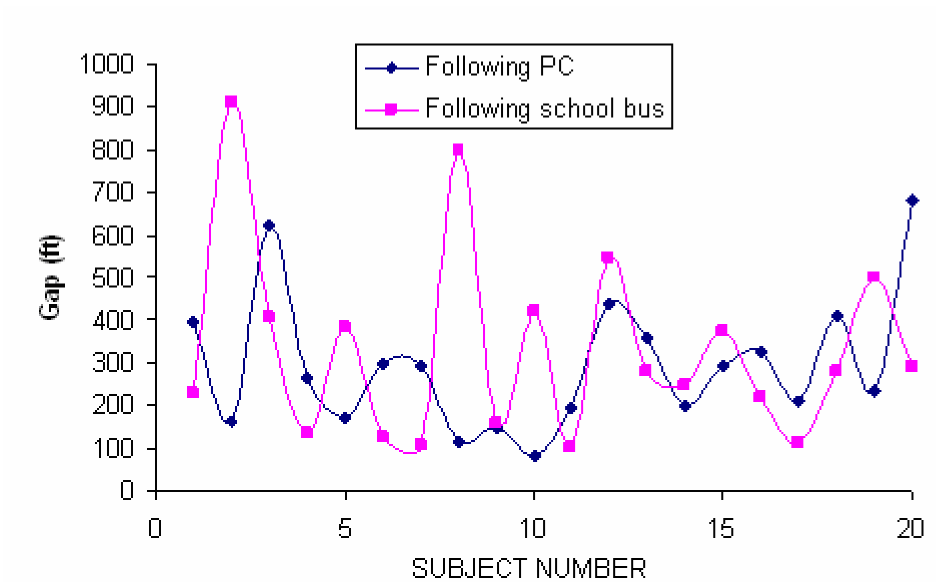

Figure 8.1.6.1: Gap for following a school bus and for following a PC

To verify this fact, a t-test was performed to compare the gap means of both samples. From the MINITAB output in table 8.1.6.2 below p-value is 0.398 which is larger than 0.05. Therefore, there is no statistical difference between the gap means of both sample means. This result can be explained by the fact the subjects driving behind larger size vehicles do not intend to pass it because they are aware that the larger size vehicle is too long to be passed safely although they are frustrated due the visibility blockage the school bus causes.

Table 8.1.6.2: MINITAB output

TWO-SAMPLE T-TEST AND CI: PC, SCHOOL BUS

```
TWO-SAMPLE T FOR PC VS SCHOOL BUS

                              SE
             N  MEAN  STDEV  MEAN
PC          20   154    112    25
SCHOOL BUS  20   187    134    30


DIFFERENCE = MU (PC) - MU (SCHOOL BUS)
ESTIMATE FOR DIFFERENCE:  -33.3711
95% CI FOR DIFFERENCE:  (-112.5015, 45.7594)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -0.86  P-VALUE = 0.398  DF = 36
```

8.1.7 Survey Analysis

As mentioned before, subjects were asked to answer a survey after they finish driving the simulator car. For vertical visibility blockage scenarios (following a PC and following a school bus) four questions were addressed to the subjects as shown in appendix D.

To start with, the subjects were asked if they saw the traffic signal pole in both following a PC and following a school bus sub-scenarios. As shown in Figure 8.1.7.1, 10 subjects who drove behind the school bus reported that they did not see the traffic signal, and the 10 other subjects driving behind the school bus reported that they saw the traffic light. The subjects that reported that they did not see the traffic signal ran the red light. Therefore, the cause of running the red light is a visibility problem.

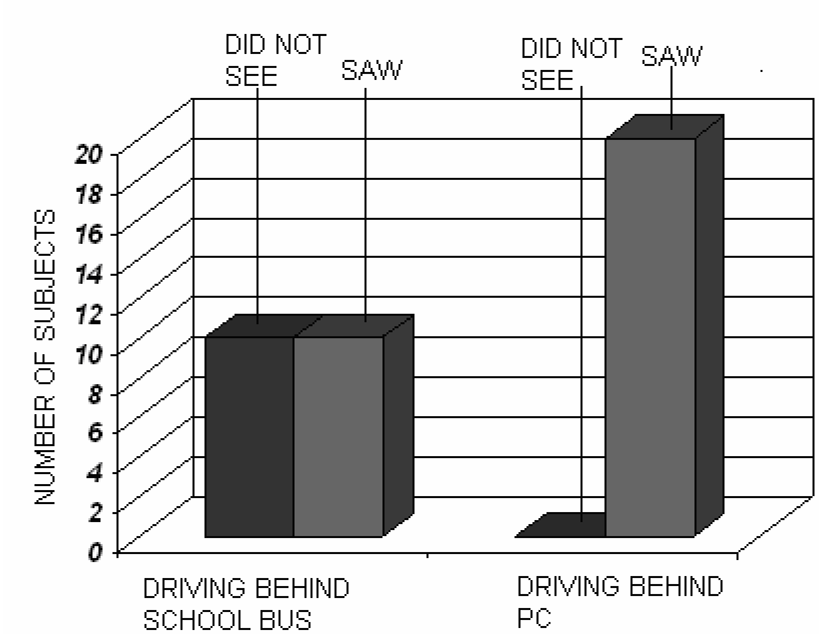

Figure 8.1.7.1: Traffic signal visibility for following a PC and following a school bus.

The same subjects were asked whether when they saw the traffic signal it was too late for them to stop. As shown in Figure 8.1.7.2, the 10 subjects who ran the red lights reported that they saw the traffic signal at some point when they were driving and that it was too late for them to stop. However, the two subjects driving behind the passenger car and ran the red light reported that they saw the traffic signal but they still ran the red light because they just decided not to stop thinking it is too late.

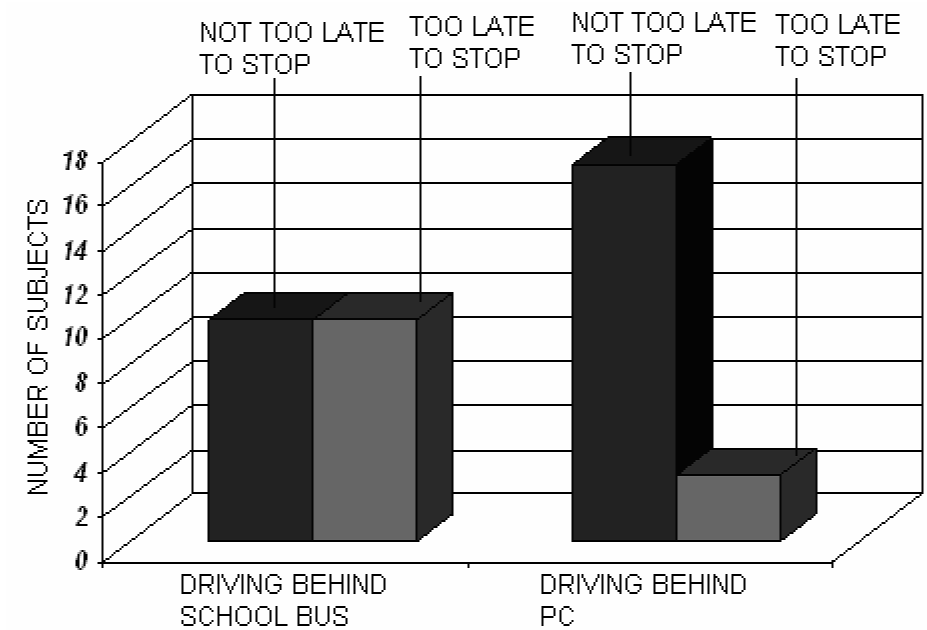

Figure 8.1.7.2: “too late to stop” following a school bus and following a PC

As shown in Figure 8.1.7.3, the 20 subjects driving behind a school bus and the other 20 subjects driving behind a passenger car were asked if they drive closely to passenger cars and buses respectively.

The ten subjects who drove behind the school bus reported that they drive close behind a large truck in daily life and the other 10 subjects who drove behind the school bus reported that they don’t drive close behind large vehicle. However, 8 subjects driving behind the passenger car reported that they drive close to passenger cars in daily life and the remaining 12 subjects driving behind a passenger car reported that they keep a large distance when they drive behind a passenger car in daily life and in similar circumstances.

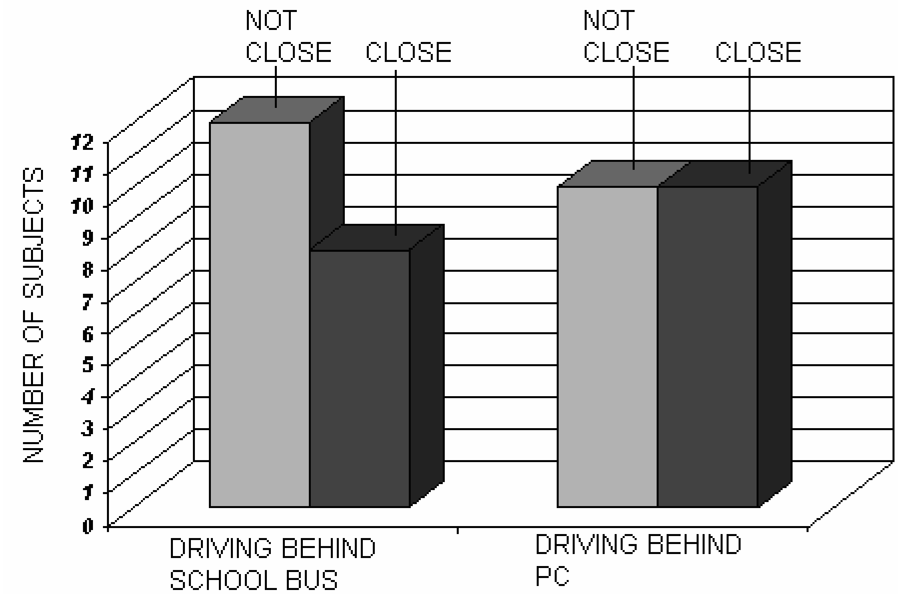

Figure 8.1.7.3: Driving close behind a school and a PC

The 20 subjects driving behind a school bus were asked if they encounter this visibility problem in their daily life. As shown in Figure 8.1.7.4, 80% of the subjects said that they come upon the vertical visibility problem in daily life causing them frustration and leading to red light running.

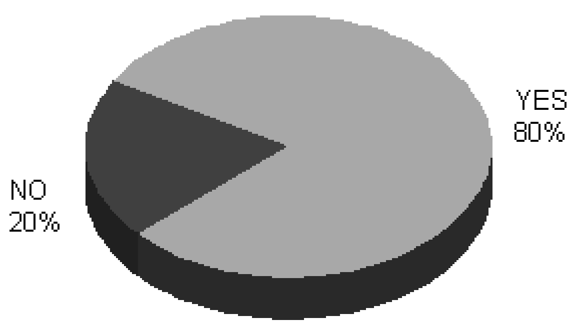

Figure 8.1.7.4: Visibility problem in daily life.

8.2 Vertical visibility blockage proposed solution

As seen in the previous section, larger size vehicles generate vertical visibility blockage of the traffic signal for the following passenger cars resulting in red light running.

8.2.1 Operating cruising velocity of the Simulator

The cruising velocities of the simulator car following the school bus and the speed of the simulator car following the school bus with the addition of the traffic signal on the right side of the road versus the speed limit, 35 mph, are shown in the Figure 8.2.1.1 below. These velocities seem realistic and reflect the same velocities driving would follow on the roads.

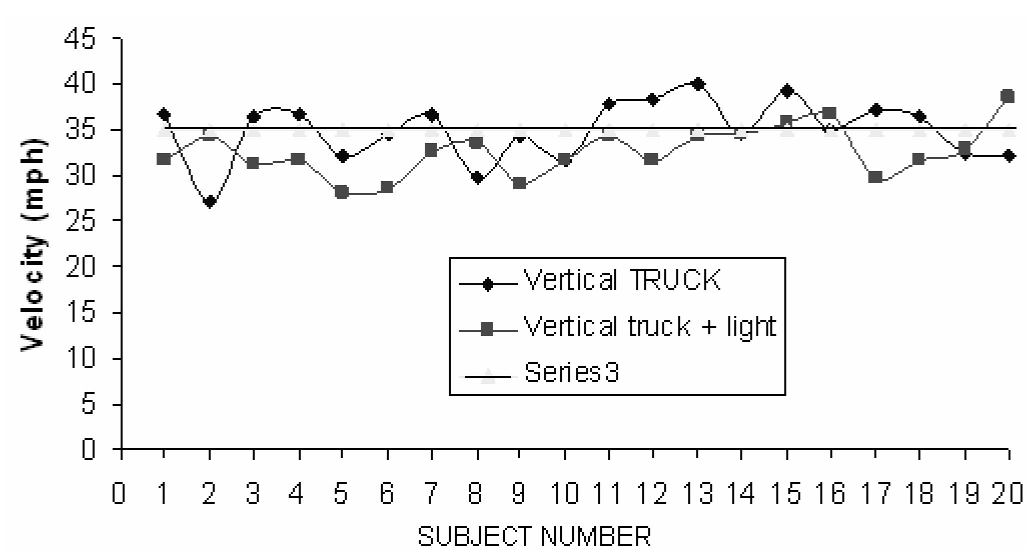

Figure 8.2.1.1: Velocities of following a school bus and a PC

8.2.2 Chi-Square Test for red light running between following a school bus and following a school bus with addition of traffic signal pole.

From the collected data, 4 subjects out of 20 subjects driving the simulator behind school bus with the additional traffic signal pole ran the red light. However, 10 subjects out of the 20 subjects driving the simulator car behind school bus ran the red light. Therefore, the probability of running the red light if following a school bus with additional traffic signal pole is: $p=\frac{4}{20}=20\%$, and the probability of running the red light if following a school bus**:**

$$p = \frac{10}{20} = 0.5 = 50\% .$$

To determine a significant statistical difference between the two ratios a chi-square test was completed.

Table 8.2.2.1 below is the output from MINITAB for the chi-square test with 95 % confidence interval. The resulting P-value is equal to 0.047 with is close to α=0.05. As a conclusion, there is a significant statistical difference between the red light running ratios for following a school bus (or a truck) with and without the additional traffic signal pole. As a conclusion, driving behind a school bus or a large truck with an extra traffic signal pole of the right side of the road decreases the potential for red light running significantly.

Table 8.2.2.1: MINITAB output

CHI-SQUARE TEST: C1, C2

```
EXPECTED COUNTS ARE PRINTED BELOW OBSERVED COUNTS
CHI-SQUARE CONTRIBUTIONS ARE PRINTED BELOW EXPECTED COUNTS

          C1      C2  TOTAL
    1      4      16     20
        7.00   13.00
       1.286   0.692

    2     10      10     20
        7.00   13.00
       1.286   0.692

TOTAL     14      26     40

CHI-SQ = 3.956, DF = 1, P-VALUE = 0.047
```

8.2.3 Deceleration rates test

As mentioned in the first section of chapter 6, the subjects that have a higher deceleration rate mean suffer from a visibility problem. 20 subjects drove the simulator behind the school bus without an additional traffic signal pole and 20 other subjects drove the simulator behind the school bus with additional traffic signal pole. However, if the simulator car runs the red light, its deceleration rate would be null since it did not stop. Therefore, the deceleration rates of 10 subjects that did not run the red light when they were driving behind the school bus without the additional traffic signal pole will be compared to the deceleration rates of the 16 subjects driving behind the school bus with the additional traffic signal pole that did not run the red light. Figure 8.2.3.1 shows the deceleration rates for both sub-scenarios which seem to be similar.

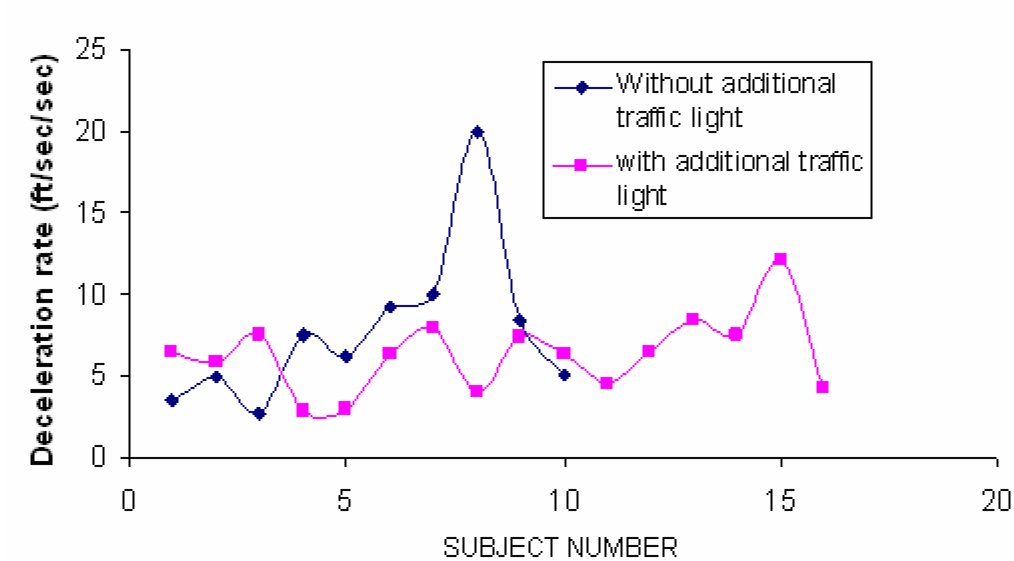

Figure 8.2.3.1: Deceleration rates of simulator for following a school bus and a PC

A 2 sample t-test was computed in MINITAB to check for a statistical significant difference between the means of both samples for 95 % confidence interval with the following hypotheses:

$$H_0 : \mu_{withlight} = \mu_{withoutlight}$$
$$H_1 : \mu_{withlight} \neq \mu_{withoutlight}$$

From the MINITAB output below the p-value is equal to 0.408 which means that there is no significant statistical difference between the deceleration means of both sub-scenarios. The deceleration mean for following the school bus is equal to 7.73 ft/sec/sec and the deceleration mean for following the school bus with additional traffic signal pole is equal to 6.30 ft/sec/sec.

Table 8.2.3.2 MINITAB output

TWO-SAMPLE T-TEST AND CI: C1, C2

```
TWO-SAMPLE T FOR C1 VS C2

     N  MEAN  STDEV  SE MEAN
C1  10  7.73   4.93      1.6
C2  16  6.30   2.32     0.58


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  1.43188
95% CI FOR DIFFERENCE:  (-2.22794, 5.09169)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = 0.86  P-VALUE = 0.408  DF = 11
```

8.2.4 Response delay time means test

This section compares the response delay times of following the school bus with and without an additional traffic signal pole. As explained earlier, when the delay response time mean for one sub-scenario is higher than the delay response time mean for another scenario, it is suggested that a visibility problem had occurred with the larger response delay time. Figure 8.2.4.1 below shows the response times for both sub-scenarios.

Similarly to the deceleration rates, if the simulator car runs the red light, its response delay time would be null since it did not stop. Therefore, the response delay time of 10 subjects that did not run the red light when they were driving behind the school bus will be compared to the response delay time of the 16 subjects driving behind the school bus with an additional traffic signal pole that did not run the red light.

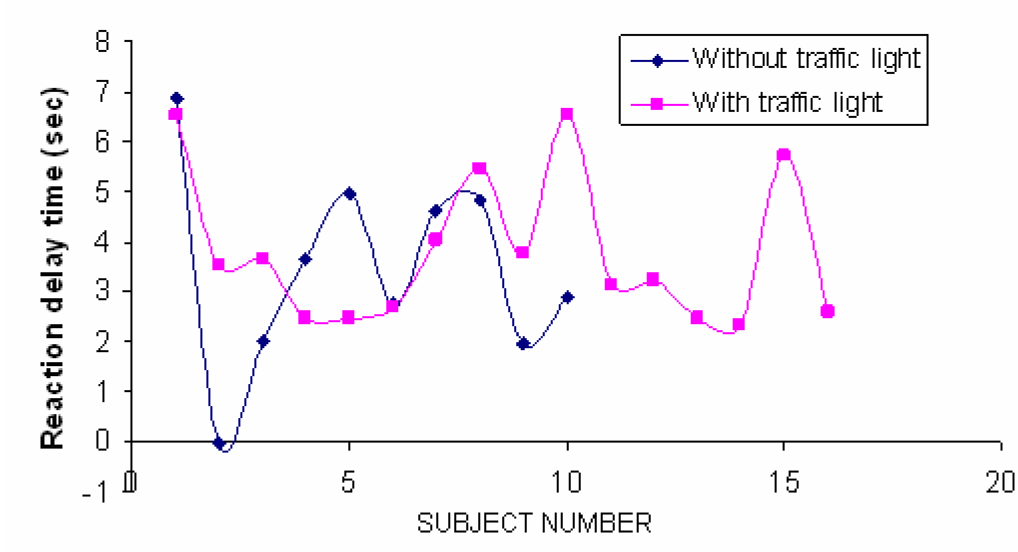

Figure 8.2.4.1- Response delay times of following a school bus and following a PC

A 2 sample t-test was computed in MINITAB to check for a statistical significant difference between the means of both samples for 95 % confidence interval with the following hypotheses:

$$H_0 : \mu_{withlight} = \mu_{withoutlight}$$
$$H_1 : \mu_{withlight} \neq \mu_{withoutlight}$$

Table 8.2.4.2 MINITAB output

TWO-SAMPLE T-TEST AND CI: C1, C2

```
TWO-SAMPLE T FOR C1 VS C2

     N  MEAN  STDEV  SE MEAN
C1  10  3.45   1.95     0.62
C2  16  3.79   1.47     0.37


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  -0.333625
95% CI FOR DIFFERENCE:  (-1.864502, 1.197252)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -0.46  P-VALUE = 0.649  DF = 15
```

From the MINITAB output above the p-value is equal to 0.649 which means that there is no significant statistical difference between the response delay times of both samples. This result is reasonable since we are comparing the response delay time for the subjects that did not run the red light.

8.2.5 Test for cruising velocity

The collected cruising velocities are the average velocities of the simulator car in both sub-scenarios just before the traffic signal pole turns amber. The purpose of testing the cruising velocities difference between the two sub-scenarios is to study the behavior of subjects driving behind large size vehicles, with and without the additional traffic signal pole, and to analyze the effect of this behavior on the red light running rate. Indeed, if the subjects are frustrated because they are driving blindly behind the bus, they might have higher speeds because of their intent to pass it. However, in the same circumstances but with an additional traffic signal pole on the right side of the road, the subjects might be more careful since they see the additional traffic signal pole and consequently slow down. From Figure 8.2.5.1 below the velocities of the simulator with additional traffic signal pole seem lower than the velocity of the simulator without additional traffic signal pole. Therefore, one can conclude that the subjects' behavior while driving behind the school bus with additional traffic signal pole were more careful because of the traffic signal pole. To confirm this conclusion, a 2 sample t-test was completed to compare the velocity means of both samples with the following hypotheses:

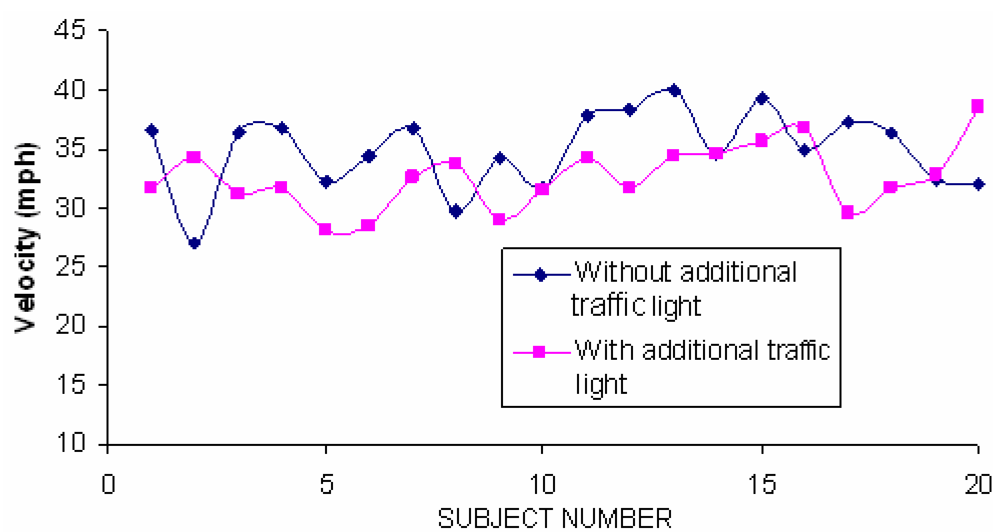

Figure 8.2.5.1: Cruising velocities for following a school with and without an additional traffic signal pole

$$H_0 : \mu_{withlight} = \mu_{withoutlight}$$
$$H_1 : \mu_{withlight} \neq \mu_{withoutlight}$$

Table 8.2.5.2: MINITAB output

TWO-SAMPLE T-TEST AND CI: C1, C2

```
TWO-SAMPLE T FOR C1 VS C2

     N   MEAN  STDEV  SE MEAN
C1  20  34.95   3.27     0.73
C2  20  32.61   2.71     0.61


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  2.34300
95% CI FOR DIFFERENCE:  (0.41673, 4.26927)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = 2.47  P-VALUE = 0.019  DF = 36
```

From the above MINITAB output the P-value is 0.019 which is less than 0.05. Therefore, the mean velocity of following a school bus equal to 34.95 mph and following a school bus with an additional traffic signal pole 32.61 mph. Therefore, the above conclusion is confirmed.

8.2.6 Test for gap

As mentioned in the first section of chapter 6, gap is also one of the important variables in our research. Figure 8.2.6.1 below most of the subjects followed the school bus with an additional traffic signal pole at a larger gap than the gap for following the school bus without an additional traffic signal pole. This also explains that the additional traffic signal pole made subjects more careful and consequently made them drive at a higher gap behind the school bus.

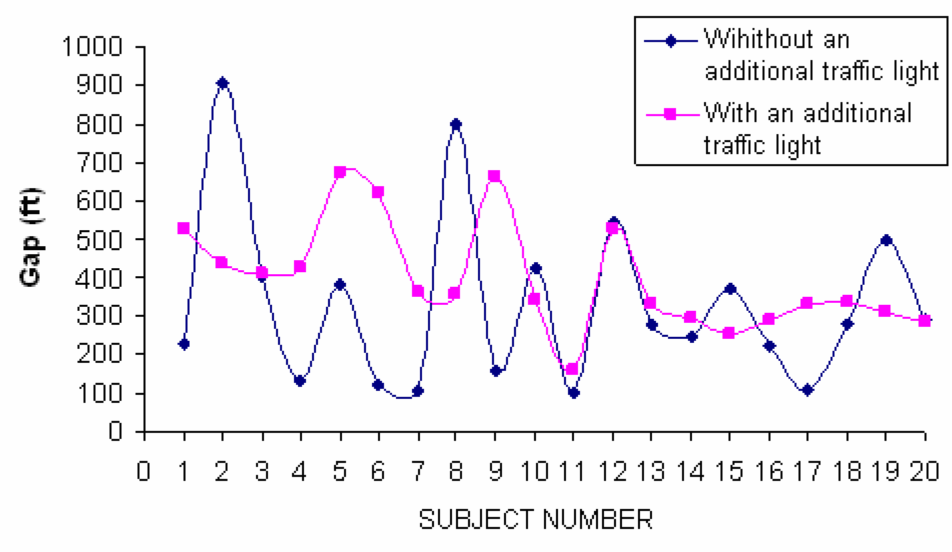

Figure 8.2.6.1: Gap for following a school bus with and without an additional traffic signal pole

To verify this fact, a t-test was performed to compare the gap means of both samples. From the MINITAB output in table 8.2.6.2 below p-value is 0.273 which is larger than 0.05. Therefore, there is no statistical difference between the gap means of both sample means.

Table 8.6.2: MINITAB output

TWO-SAMPLE T-TEST AND CI: C1, C2

```
TWO-SAMPLE T FOR C1 VS C2

                        SE
     N  MEAN  STDEV   MEAN
C1  20   331    223     50
C2  20   397    140     31


DIFFERENCE = MU (C1) - MU (C2)
ESTIMATE FOR DIFFERENCE:  -65.6413
95% CI FOR DIFFERENCE:  (-185.5911, 54.3084)
T-TEST OF DIFFERENCE = 0 (VS NOT =): T-VALUE = -1.12  P-VALUE = 0.273  DF = 31
```

8.2.7 Survey Analysis

As mentioned before, all the subjects were asked to take a survey once they complete the experiment. One of the questions that the subjects were asked was which traffic signal pole they saw first. As shown in Figure 8.2.7.1, 70 % of the subjects said that they saw the additional traffic signal pole on the side of the road before they saw originally installed traffic signal pole and 30 % of the subject said that they saw them at the same time.

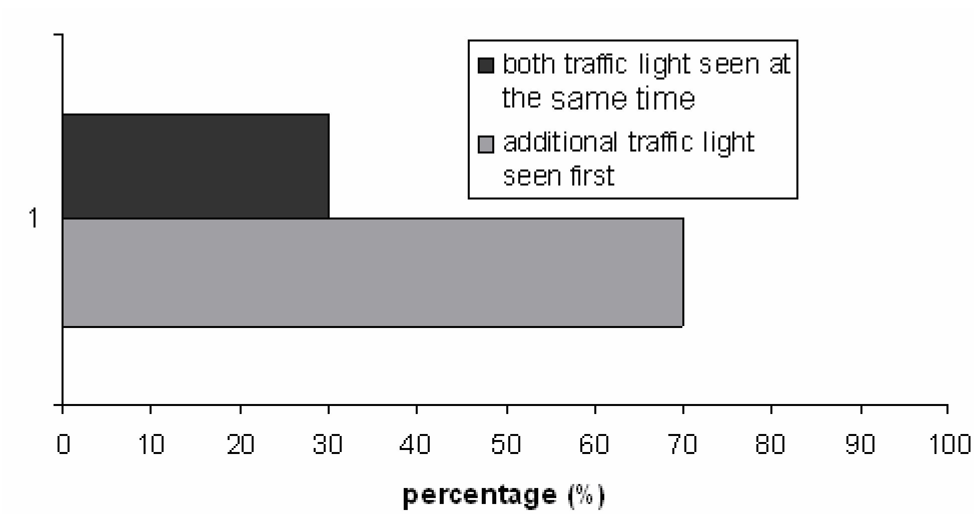

Figure 8.2.7.1: traffic signal poles visibility

The subjects were also asked if they think that the traffic signal pole addition would be profitable for the drivers' safety in real life. As shown in Figure 8.2.7.2, 65% of the subjects said that it is profitable and the remaining subjects said that it is not profitable.

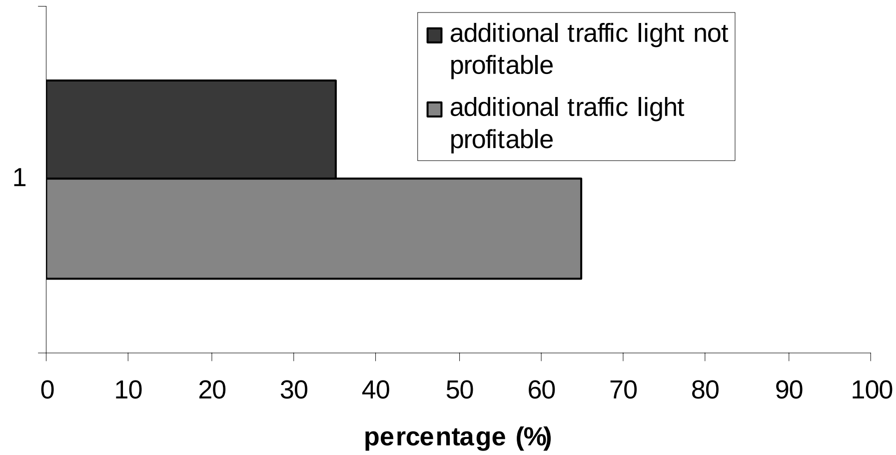

Figure 8.2.7.2: Additional traffic signal pole evaluation for real life.

8.3 Conclusions

One of the objectives of the research is to study whether driving behind a larger size vehicle such as school buses increases the rate of red light running on signalized intersections. From the above analysis, it was confirmed that there is a significant statistical difference between the rates of red light running for following a passenger car and for following a larger size vehicle with a higher rates of red light running for driving behind a larger size vehicle due to vertical visibility blockage of the traffic signal pole.

Another objective was to study the behavior of the subjects driving behind larger size vehicles. From the analysis above it was confirmed that there is no statistical difference between the velocities of the two samples. Therefore, one can conclude that subjects driving a larger size vehicle do not speed more than they speed when they drive behind a passenger car for the reason that they know that it is hard to pass a larger size vehicle although they are frustrated because the visibility beyond the larger size vehicle is obstructed by the latter. From the above analysis, it was also confirmed that there is no statistical difference between the gap means for following a PC or following a lager size vehicle. This behavior can be explained by the same reasons that subjects know that it is too hard and dangerous to pass the school bus although they are frustrated.

From the above analysis, one can conclude that the red light running rate when following a larger size vehicle through signalized intersections is higher than the red light running rate when following a passenger due to vertical visibility blockage of the traffic. However, the behavior of the subjects does not contribute to red running rate.

The proposed addition of the traffic signal pole on the right side of the road profitability was also tested. From the above analysis, the red light running rate decreased significantly and 65 % of the subjects that completed the experiment said that the traffic signal pole would be profitable for use in real life. Finally, the addition of the traffic signal pole on the right side of the road reduces the red light running rate and consequently increases the safety of the drivers.

CHAPTER 9: CONCLUSIONS

Vertical and horizontal visibility blockages and their consequences on the safety of traffic were the major issue of our research. To study the seriousness of these issues, 5 sub-scenarios were designed in the UCF driving simulator as explained before. And the resulting data were thoroughly analyzed and conclusions were made.

For the horizontal visibility blockage, two sub-scenarios were designed, and the results confirmed that LTVs contribute to the increase of rear-end collisions on the roads. This fact is due to the horizontal visibility blockage LTVs cause and consequently due to the following driver's behavior when he/she drives behind an LTV. Indeed, the results showed that passenger car drivers behind LTVs are prone to speed more and to keep a small gap with the latter relatively to driving behind passenger cars. This behavior is probably due to drivers' frustration and their eagerness to pass the LTV. Moreover, the trend of the impact velocities shows a higher impact velocities when vehicles follow an LTV, therefore rear-end collisions with LTVs are more severe than rear-end collisions when following a passenger car. From the survey analysis 65% of the subjects said that they drive close to LTVs in real life. Therefore, the horizontal visibility blockage is a problem that occurs in real life and should be taken into serious consideration for the safety of the passenger car drivers.

As for the vertical visibility blockage, three sub-scenarios were designed in the driving simulator, and the results confirmed that LSVs increases the rate of red light running significantly due to vertical visibility blockage of the traffic signal pole. However, the behavior of the drivers when they drive behind LSVs is not different then their behavior when drive behind passenger cars. In fact, the velocities and gaps were similar which is due to the fact that subjects driving behind an LSV know that the LSV is too long and that it is too hard to pass it. Therefore, although the drivers are frustrated behind the LSVs, they know that they cannot pass it; therefore they keep normal gaps and velocities waiting for the LSV to change its path.

The suggested addition of the traffic signal pole on the side of the road significantly decreased the red light running rate. Moreover, 65% of the subjects driving behind an LSV with the proposed additional traffic signal pole said that the traffic signal pole is profitable and that it should be applied to real world. Therefore, since red light running can cause accidents and safety threat for drivers and since the additional traffic signal pole decreased the red light running rate, the addition of traffic signal poles on the right side of the road is a profitable countermeasure that may help enhance driving safety at signalized intersections.

APPENDIX A: VISUAL BASIC C CODES

A1: Horizontal visibility blockage scenario code

```
#include<stdio.h>
#include<math.h>
#include<stdlib.h>
#define N 8000

void INPUT(double *,double *,double *,double *,double *,double *,double *,double
*,double *,
                        double *);
void SOLVE(double *,double *,double *,double *,double *,double *,double *,double
*,double *,
                        double *,double *,double *,double *,double *,int *,int *,double *);
void OUTPUT(double,double,double,double,int,int,double);

main()
{
  int l,j,r,s;
  double t[N],x[N],y[N],SI[N],AI[N],BI[N],V[N],X1[N],Y1[N],V1[N];
  double D, RT, v, g, d;

  printf("How many simulation data sets do you have?\n\n");
  scanf("%d", &l);
  for (j=1; j<=l; j++)
  {
        INPUT(t,x,y,SI,AI,BI,V,X1,Y1,V1);
        SOLVE(t,x,y,SI,AI,BI,V,X1,Y1,V1,&D,&RT,&v,&g,&r,&s,&d);
        OUTPUT(D,RT,v,g,r,s,d);
        }

        printf("\nThank you for using this program.\n\n");
  return 0;
}

void INPUT(double *t, double *x, double *y, double *SI, double *AI, double *BI, double
*V,
                        double *X1, double *Y1, double *V1)
{
        int i;
        char PATH[30];
        FILE *INFO;

        printf("\nPlease enter the text file name for one simulation data, in the form:\n");
```

```
        printf("drive:name.ext\n\n");
        scanf("%s", PATH);
        INFO = fopen(PATH, "r");
        for (i=0; i<=N-1; i++)
        {
                fscanf(INFO, "%lf%lf%lf%lf%lf%lf%lf%lf%lf%lf",
&t[i],&x[i],&y[i],&SI[i],&AI[i],&BI[i],&V[i],&X1[i],&Y1[i],&V1[i]);
                fscanf(INFO, "\n");
        }
        fclose(INFO);
}

void SOLVE(double *t,double *x,double *y,double *SI,double *AI,double *BI,double
*V,double *X1,
                        double *Y1,double *V1,double *D,double *RT,double *v,double
*g,int *r,
                        int *s, double *d)

{
        int o,i,f,h;
        *r=0;
   *s=0;

        for(h=1; h<=N-1; h++)
        {
                if(X1[h]<=10644.76)
                {
                        o=h;
                        break;
                }
        }
        printf("\nto: %lf", t[o]);

        for(h=o; h<=N-1; h++)
        {
                if(BI[h]>0)
                {
                        i=h-1;
                        break;
                }
        }
        printf("\nti: %lf", t[i]);

        for(h=i; h<=N-1; h++)
        {
                if(BI[h]>0 && V[h]==0)
```

```
			{
				f=h;
				break;
			}
		}

		printf("\ntf: %lf\n", t[f]);
		*D=V[i]*1.4666667/(t[f]-t[i]);
		*RT=t[i]-t[o];
		*v=V[i];
		*g=x[h]-X1[h];

		for(h=o; h<=N-1; h++)
		{
			if(t[h]>t[o]+3.5 && x[h]<=10590)
			{
				*r=1;
				break;
			}
		}

		for(h=o; h<=N-1; h++)
		{
			if(t[h]>t[o]+3.5 && x[h]<=10590 && x[h]>=10572 && V[h]==0)
			{
				*s=1;
				break;
			}
		}

		*d= 10588-x[i];
}

void OUTPUT(double D,double RT,double v,double g,int r,int s,double d)
{
		char PATH[30];
		FILE *SOL;

		printf("\nEnter the desired path for your solution in the form - drive:name.ext\n\n");
		scanf("%s", PATH);
		SOL = fopen(PATH, "w");
		fprintf(SOL, "Deceleration Rate: %lf ft/s2\n", D);
		fprintf(SOL, "Response Time: %lf s\n", RT);
		fprintf(SOL, "Initial Velocity: %lf mph\n", v);
		fprintf(SOL, "Gap: %lf m\n", g);
		fprintf(SOL, "Rate of stop: %d\n", r);
```

```
        fprintf(SOL, "Stopped in the middle of the intersection: %d\n", s);
        fprintf(SOL, "Distance from amber to intersection: %lf m\n", d);
        fclose(SOL);
}
```

A2: Vertical visibility blockage scenario code

```
#include<stdio.h>
#include<math.h>
#include<stdlib.h>
#define N 8000

void INPUT(double *,double *,double *,double *,double *,double *,double *,double
*,double *,
                        double *);
void SOLVE(double *,double *,double *,double *,double *,double *,double *,double
*,double *,
                        double *,double *,double *,double *,double *,int *,int *,double *);
void OUTPUT(double,double,double,double,int,int,double);

main()
{
  int l,j,r,s;
  double t[N],x[N],y[N],SI[N],AI[N],BI[N],V[N],X1[N],Y1[N],V1[N];
  double D, RT, v, g, d;

  printf("How many simulation data sets do you have?\n\n");
  scanf("%d", &l);
  for (j=1; j<=l; j++)
  {
        INPUT(t,x,y,SI,AI,BI,V,X1,Y1,V1);
        SOLVE(t,x,y,SI,AI,BI,V,X1,Y1,V1,&D,&RT,&v,&g,&r,&s,&d);
        OUTPUT(D,RT,v,g,r,s,d);
        }

        printf("\nThank you for using this program.\n\n");
  return 0;
}

void INPUT(double *t, double *x, double *y, double *SI, double *AI, double *BI, double
*V,
                        double *X1, double *Y1, double *V1)
{
        int i;
        char PATH[30];
        FILE *INFO;

        printf("\nPlease enter the text file name for one simulation data, in the form:\n");
        printf("drive:name.ext\n\n");
```

```
	scanf("%s", PATH);
	INFO = fopen(PATH, "r");
	for (i=0; i<=N-1; i++)
	{
		fscanf(INFO, "%lf%lf%lf%lf%lf%lf%lf%lf%lf%lf",
&t[i],&x[i],&y[i],&SI[i],&AI[i],&BI[i],&V[i],&X1[i],&Y1[i],&V1[i]);
		fscanf(INFO, "\n");
	}
	fclose(INFO);
}

void SOLVE(double *t,double *x,double *y,double *SI,double *AI,double *BI,double
*V,double *X1,
			double *Y1,double *V1,double *D,double *RT,double *v,double
*g,int *r,
			int *s, double *d)

{
	int o,i,f,h;
	*r=0;
   *s=0;

	for(h=1; h<=N-1; h++)
	{
		if(X1[h]<=10644.76)
		{
			o=h;
			break;
		}
	}
	printf("\nto: %lf", t[o]);

	for(h=o; h<=N-1; h++)
	{
		if(BI[h]>0)
		{
			i=h-1;
			break;
		}
	}
	printf("\nti: %lf", t[i]);

	for(h=i; h<=N-1; h++)
	{
		if(BI[h]>0 && V[h]==0)
		{
```

```
				f=h;
				break;
			}
		}

		printf("\ntf: %lf\n", t[f]);
		*D=V[i]*1.4666667/(t[f]-t[i]);
		*RT=t[i]-t[o];
		*v=V[i];
		*g=x[h]-X1[h];

		for(h=o; h<=N-1; h++)
		{
			if(t[h]>t[o]+3.5 && x[h]<=10590)
			{
				*r=1;
				break;
			}
		}

		for(h=o; h<=N-1; h++)
		{
			if(t[h]>t[o]+3.5 && x[h]<=10590 && x[h]>=10572 && V[h]==0)
			{
				*s=1;
				break;
			}
		}

		*d= 10588-x[i];
}

void OUTPUT(double D,double RT,double v,double g,int r,int s,double d)
{
		char PATH[30];
		FILE *SOL;

		printf("\nEnter the desired path for your solution in the form - drive:name.ext\n\n");
		scanf("%s", PATH);
		SOL = fopen(PATH, "w");
		fprintf(SOL, "Deceleration Rate: %lf ft/s2\n", D);
		fprintf(SOL, "Response Time: %lf s\n", RT);
		fprintf(SOL, "Initial Velocity: %lf mph\n", v);
		fprintf(SOL, "Gap: %lf m\n", g);
		fprintf(SOL, "Rate of stop: %d\n", r);
		fprintf(SOL, "Stopped in the middle of the intersection: %d\n", s);
```

```
        fprintf(SOL, "Distance from amber to intersection: %lf m\n", d);
        fclose(SOL);
}
```

APPENDIX B: RAW DATA OUTPUT SAMPLE

Table B1: Vertical visibility blockage scenario sample data output

User Information
Subject#:5
Name:cindy
Gender:f
Age:26
Scenario:vertical_truck

sim_time	x_position	y_position	steering_input	accelerator_input	brake_input	speed	vechicle1_x	vechicle1_y	vechicle1_speed
8.95	11142.1	6556	0.017113	0	0	0	11038	6426	0
8.966666	11142.1	6556	0.017113	0	0	0	11038	6426	0
8.983334	11142.1	6556	0.017113	0	0	0	11038	6426	0
9	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.016666	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.033334	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.05	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.066667	11142.1	6556	0.017113	0.138121	0	0	11038	6426	0
9.083333	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.1	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.116667	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.133333	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.15	11142.1	6556	0.017113	0	0	0	11038	6426	0
9.166667	11142.1	6556	0.017113	0	0	0	11038	6426	0
93.56667	10516.01	6351.478	-0.35262	0	49.4431	33.28149	10461.97	6351.8	34.85054
93.58334	10515.76	6351.475	-0.35262	0	50.0647	33.28066	10461.71	6351.8	34.85054
93.6	10515.51	6351.473	-0.35262	0	50.6863	33.27995	10461.45	6351.8	34.85054
93.61667	10515.26	6351.47	-0.35262	0	52.3439	33.14894	10461.19	6351.8	34.85054
93.63333	10515.02	6351.469	-0.35262	0	52.7583	33.1479	10460.93	6351.8	34.85054
93.65	10514.77	6351.468	-0.35215	0	53.3799	33.01656	10460.67	6351.8	34.85054
93.66666	10514.52	6351.467	-0.3498	0	53.7943	32.88535	10460.42	6351.8	34.71952
93.68333	10514.28	6351.467	-0.34587	0	54.4159	32.88528	10460.16	6351.8	34.85054
93.7	10514.04	6351.468	-0.341	0	55.4519	32.75433	10459.9	6351.8	34.85054
93.71667	10513.79	6351.469	-0.3341	0	56.0735	32.62352	10459.64	6351.8	34.85054
93.73333	10513.55	6351.47	-0.32452	0	56.4879	32.4925	10459.38	6351.8	34.85054
93.75	10513.31	6351.472	-0.31165	0	56.2807	32.49329	10459.12	6351.8	34.85054
93.76667	10513.07	6351.474	-0.29626	0.184162	57.1095	32.36228	10458.86	6351.8	34.85054
93.78333	10512.83	6351.477	-0.27993	0	57.5239	32.2326	10458.6	6351.8	34.85054
93.8	10512.59	6351.479	-0.26329	0	58.3527	32.10159	10458.34	6351.8	34.85054
93.81667	10512.35	6351.483	-0.24618	0.184162	58.7671	31.97146	10458.08	6351.8	34.85054
93.83334	10512.11	6351.486	-0.22812	0	58.3527	31.84045	10457.82	6351.8	34.85054
93.85	10511.87	6351.491	-0.20803	0	58.9743	31.84261	10457.56	6351.8	34.85054
93.86667	10511.64	6351.495	-0.18463	0.138121	59.1815	31.58062	10457.3	6351.8	34.85054
93.88333	10511.4	6351.5	-0.16202	0	60.0103	31.58062	10457.04	6351.8	34.85054
93.9	10511.17	6351.504	-0.1391	0	60.4247	31.31993	10456.78	6351.8	34.85054
93.91666	10510.94	6351.51	-0.11775	0	61.0463	31.19039	10456.52	6351.8	34.85054

93.93333	10510.71	6351.515	-0.09734	0	61.2535	31.19039	10456.26	6351.8	34.85054
93.95	10510.47	6351.521	-0.07772	0	61.4607	30.92843	10456	6351.8	34.85054
93.96667	10510.25	6351.526	-0.05966	0	61.6679	30.79905	10455.74	6351.8	34.85054
93.98333	10510.02	6351.532	-0.0438	0	62.4967	30.66807	10455.48	6351.8	34.85054
94	10509.79	6351.538	-0.02873	0	62.0823	30.5371	10455.22	6351.8	34.85054
94.01667	10509.56	6351.544	-0.01476	0	62.9111	30.40789	10454.96	6351.8	34.85054
94.03333	10509.34	6351.551	-0.00361	0	62.4967	30.14596	10454.7	6351.8	34.85054
94.05	10509.11	6351.557	0.005338	0	62.7039	30.14418	10454.44	6351.8	34.85054
94.06667	10508.89	6351.563	0.013031	0.552486	62.4967	29.88403	10454.18	6351.8	34.85054
94.08334	10508.67	6351.569	0.020724	0	62.7039	29.75307	10453.92	6351.8	34.85054
94.1	10508.45	6351.576	0.028417	0	62.4967	29.6221	10453.66	6351.8	34.85054
94.11667	10508.23	6351.582	0.03611	0	62.4967	29.36018	10453.4	6351.8	34.85054
94.13333	10508.01	6351.589	0.042233	0	63.9471	29.36215	10453.14	6351.8	34.85054
94.15	10507.79	6351.595	0.0471	0	64.7759	29.09641	10452.88	6351.8	34.85054
94.16666	10507.58	6351.601	0.051496	0	65.3975	28.83633	10452.62	6351.8	34.85054
94.18333	10507.36	6351.607	0.055264	0	65.81191	28.83633	10452.36	6351.8	34.85054
94.2	10507.15	6351.614	0.058404	0	65.81191	28.57442	10452.1	6351.8	34.85054
94.21667	10506.94	6351.62	0.060759	0	65.3975	28.3106	10451.84	6351.8	34.85054
94.23333	10506.73	6351.625	0.062957	0	65.81191	28.17964	10451.58	6351.8	34.85054
94.25	10506.52	6351.631	0.064841	0	65.3975	28.04867	10451.32	6351.8	34.85054
94.26667	10506.32	6351.637	0.066882	0	65.81191	27.65578	10451.06	6351.8	34.85054
94.28333	10506.11	6351.643	0.06908	0	66.2263	27.65399	10450.8	6351.8	34.85054
94.3	10505.91	6351.648	0.070964	0	66.2263	27.39205	10450.54	6351.8	34.85054
94.31667	10505.7	6351.653	0.072848	0	66.2263	27.13011	10450.28	6351.8	34.85054
94.33334	10505.5	6351.659	0.074575	0	66.2263	26.99914	10450.02	6351.8	34.85054
94.35	10505.3	6351.664	0.075831	0	66.4335	26.73551	10449.76	6351.8	34.85054
94.36667	10505.1	6351.668	0.076302	0	67.0551	26.60453	10449.5	6351.8	34.85054
94.38333	10504.91	6351.673	0.076459	0	67.46951	26.34103	10449.25	6351.8	34.85054
94.4	10504.71	6351.678	0.076459	0	68.2983	26.08063	10448.99	6351.8	34.85054
94.41666	10504.52	6351.682	0.076459	0	68.2983	26.07906	10448.73	6351.8	34.85054
94.43333	10504.33	6351.687	0.076459	0	68.7127	25.68611	10448.47	6351.8	34.71952
94.45	10504.14	6351.69	0.076459	0	68.7127	25.5537	10448.21	6351.8	34.85054
94.46667	10503.95	6351.694	0.076459	0	69.1271	25.29173	10447.95	6351.8	34.85054
94.48333	10503.76	6351.698	0.076459	0	69.1271	25.16074	10447.69	6351.8	34.85054
94.5	10503.58	6351.702	0.076459	0	68.9199	24.89876	10447.43	6351.8	34.85054
94.51667	10503.39	6351.706	0.076459	0	69.1271	24.63678	10447.17	6351.8	34.85054
94.53333	10503.21	6351.71	0.076459	0	69.1271	24.5058	10446.91	6351.8	34.85054
94.55	10503.03	6351.713	0.076459	0	69.1271	24.37349	10446.65	6351.8	34.85054
94.56667	10502.85	6351.717	0.076459	0	69.33431	23.98051	10446.39	6351.8	34.85054
94.58334	10502.67	6351.72	0.076302	0	69.5415	23.98051	10446.13	6351.8	34.85054
94.6	10502.5	6351.724	0.076302	0	70.3703	23.58753	10445.87	6351.8	34.85054
94.61667	10502.32	6351.727	0.076145	0	70.99191	23.45654	10445.61	6351.8	34.85054
94.63333	10502.15	6351.73	0.076145	0	72.4423	23.19335	10445.35	6351.8	34.85054
94.65	10501.98	6351.733	0.076145	0	72.85671	23.06356	10445.09	6351.8	34.85054
94.66666	10501.81	6351.736	0.076145	0	73.6855	22.80036	10444.83	6351.8	34.85054
94.68333	10501.64	6351.74	0.076145	0	74.7215	22.5396	10444.57	6351.8	34.85054
94.7	10501.47	6351.743	0.076145	0	75.3431	22.27637	10444.31	6351.8	34.85054

94.71667	10501.31	6351.746	0.075988	0	76.5863	22.14537	10444.05	6351.8	34.85054
94.73333	10501.14	6351.749	0.075988	0	78.03671	21.88338	10443.79	6351.8	34.85054
94.75	10500.98	6351.751	0.075988	0	79.0727	21.4893	10443.53	6351.8	34.85054
94.76667	10500.82	6351.754	0.075831	0	79.69431	21.3594	10443.27	6351.8	34.85054
94.78333	10500.67	6351.756	0.075674	0.138121	81.1447	21.09629	10443.01	6351.8	34.85054
94.8	10500.51	6351.759	0.075674	0	82.1807	20.83542	10442.75	6351.8	34.85054
94.81667	10500.36	6351.762	0.075517	0	83.6311	20.57229	10442.49	6351.8	34.85054
94.83334	10500.21	6351.764	0.07536	0	84.87431	20.31029	10442.23	6351.8	34.85054
94.85	10500.06	6351.767	0.075203	0	86.1175	19.91729	10441.97	6351.8	34.85054
94.86667	10499.91	6351.769	0.075046	0	87.1535	19.65431	10441.71	6351.8	34.85054
94.88333	10499.77	6351.771	0.075046	0	87.9823	19.2623	10441.45	6351.8	34.85054
94.9	10499.63	6351.773	0.075046	0	89.8471	18.99928	10441.19	6351.8	34.85054
94.91666	10499.49	6351.775	0.075046	0	90.26151	18.73727	10440.93	6351.8	34.85054
94.93333	10499.35	6351.777	0.075046	0	90.26151	18.34426	10440.67	6351.8	34.85054
94.95	10499.22	6351.779	0.075046	0	91.5047	17.95125	10440.41	6351.8	34.85054
94.96667	10499.08	6351.78	0.075046	0	91.7119	17.6884	10440.15	6351.8	34.85054
94.98333	10498.96	6351.782	0.075046	0	91.5047	17.29624	10439.89	6351.8	34.85054
95	10498.83	6351.784	0.075046	0	92.3335	16.90235	10439.63	6351.8	34.85054
95.01667	10498.71	6351.786	0.075046	0	92.9551	16.64123	10439.38	6351.8	34.85054
95.03333	10498.58	6351.787	0.075046	0	93.3695	16.24731	10439.12	6351.8	34.85054
95.05	10498.47	6351.789	0.075046	0	93.78391	15.98529	10438.86	6351.8	34.85054
95.06667	10498.35	6351.79	0.075046	0.184162	94.1983	15.59158	10438.6	6351.8	34.85054
95.08334	10498.24	6351.791	0.075046	0	95.0271	15.33026	10438.34	6351.8	34.85054
95.1	10498.13	6351.792	0.075046	0	94.8199	14.80623	10438.08	6351.8	34.85054
95.11667	10498.02	6351.794	0.075046	0	95.23431	14.67523	10437.82	6351.8	34.85054
95.13333	10497.91	6351.795	0.075046	0	95.44151	14.15045	10437.56	6351.8	34.85054
95.15	10497.81	6351.796	0.075046	0	95.44151	13.8892	10437.3	6351.8	34.85054
95.16666	10497.71	6351.797	0.075046	0	95.44151	13.62641	10437.04	6351.8	34.85054
95.18333	10497.61	6351.799	0.075046	0	95.44151	13.36519	10436.78	6351.8	34.85054
95.2	10497.51	6351.8	0.075046	0	95.44151	12.97135	10436.52	6351.8	34.71952
95.21667	10497.41	6351.801	0.075046	0	94.8199	12.70933	10436.26	6351.8	34.85054
95.23333	10497.32	6351.802	0.075046	0	94.6127	12.3163	10436	6351.8	34.85054
95.25	10497.23	6351.803	0.075046	0	95.44151	12.05517	10435.74	6351.8	34.85054
95.26667	10497.15	6351.804	0.075046	0	95.0271	11.66126	10435.48	6351.8	34.85054
95.28333	10497.06	6351.805	0.075046	0	95.23431	11.39924	10435.22	6351.8	34.85054
95.3	10496.98	6351.806	0.075046	0	95.44151	11.00621	10434.96	6351.8	34.85054
95.31667	10496.9	6351.807	0.075046	0	95.0271	10.7442	10434.7	6351.8	34.85054
95.33334	10496.82	6351.808	0.075046	0	95.44151	10.61319	10434.44	6351.8	34.85054
95.35	10496.74	6351.809	0.075046	0	95.23431	10.21954	10434.18	6351.8	34.85054
95.36667	10496.67	6351.81	0.075046	0	94.8199	9.958159	10433.92	6351.8	34.85054
95.38333	10496.6	6351.811	0.075046	0	95.0271	9.565144	10433.66	6351.8	34.85054
95.4	10496.53	6351.811	0.075046	0	94.8199	9.171429	10433.4	6351.8	34.85054
95.41666	10496.46	6351.812	0.075046	0	95.0271	8.910125	10433.14	6351.8	34.85054
95.43333	10496.4	6351.813	0.075046	0	95.0271	8.647375	10432.88	6351.8	34.85054
95.45	10496.34	6351.813	0.075046	0	95.0271	8.123322	10432.62	6351.8	34.85054
95.46667	10496.28	6351.813	0.075046	0	94.6127	7.861298	10432.36	6351.8	34.85054
95.48333	10496.22	6351.814	0.075046	0	94.6127	7.599273	10432.1	6351.8	34.85054

95.5	10496.17	6351.814	0.075046	0	94.6127	7.337249	10431.84	6351.8	34.85054
95.51667	10496.12	6351.815	0.075046	0	94.4055	6.944214	10431.58	6351.8	34.85054
95.53333	10496.07	6351.815	0.075046	0	94.8199	6.681871	10431.32	6351.8	34.85054
95.55	10496.02	6351.815	0.075046	0	94.8199	6.420171	10431.06	6351.8	34.85054
95.56667	10495.97	6351.816	0.075046	0	94.4055	6.158151	10430.8	6351.8	34.85054
95.58334	10495.93	6351.816	0.075046	0	94.4055	5.896132	10430.54	6351.8	34.85054
95.6	10495.89	6351.817	0.075046	0.04604	94.4055	5.634115	10430.28	6351.8	34.85054
95.61667	10495.85	6351.817	0.075046	0.230202	94.1983	5.3717	10430.02	6351.8	34.85054
95.63333	10495.81	6351.817	0.075046	0	94.1983	5.110086	10429.76	6351.8	34.85054
95.65	10495.77	6351.818	0.075046	0	93.9911	4.97908	10429.5	6351.8	34.85054
95.66666	10495.74	6351.818	0.075046	0	94.1983	4.586065	10429.25	6351.8	34.85054
95.68333	10495.7	6351.819	0.075046	0	93.9911	4.455062	10428.99	6351.8	34.85054
95.7	10495.67	6351.819	0.075046	0	94.1983	4.062057	10428.73	6351.8	34.85054
95.71667	10495.64	6351.82	0.075046	0	93.9911	3.931058	10428.47	6351.8	34.85054
95.73333	10495.62	6351.82	0.075046	0	93.78391	3.80006	10428.21	6351.8	34.85054
95.75	10495.59	6351.821	0.075046	0	93.57671	3.407074	10427.95	6351.8	34.85054
95.76667	10495.57	6351.821	0.075046	0	93.9911	3.276082	10427.69	6351.8	34.85054
95.78333	10495.54	6351.822	0.075046	0	94.1983	3.014105	10427.43	6351.8	34.85054
95.8	10495.52	6351.822	0.075046	0	93.57671	2.751359	10427.17	6351.8	34.85054
95.81667	10495.5	6351.822	0.075046	0	93.57671	2.62116	10426.91	6351.8	34.85054
95.83334	10495.49	6351.822	0.075046	0	93.57671	2.358307	10426.65	6351.8	34.85054
95.85	10495.48	6351.822	0.075046	0	93.57671	0.393051	10426.39	6351.8	34.85054
95.86667	10495.48	6351.822	0.075046	0	93.57671	0	10426.13	6351.8	34.85054
95.88333	10495.48	6351.822	0.075046	0	93.1623	0.131017	10425.87	6351.8	34.85054
95.9	10495.48	6351.822	0.075046	0	93.3695	0	10425.61	6351.8	34.85054
95.91666	10495.48	6351.822	0.075046	0	93.1623	0	10425.35	6351.8	34.85054
95.93333	10495.48	6351.822	0.075046	0	93.1623	0.131017	10425.09	6351.8	34.85054
95.95	10495.48	6351.822	0.075046	0	93.1623	0.131017	10424.83	6351.8	34.85054
95.96667	10495.48	6351.822	0.075046	0	93.1623	0	10424.57	6351.8	34.71952
95.98333	10495.48	6351.822	0.075046	0	92.9551	0.131017	10424.31	6351.8	34.85054
96	10495.48	6351.822	0.075046	0	93.3695	0.131017	10424.05	6351.8	34.85054
96.01667	10495.48	6351.822	0.075046	0	92.7479	0	10423.79	6351.8	34.85054
96.03333	10495.48	6351.822	0.075046	0	92.7479	0.131017	10423.53	6351.8	34.85054
96.05	10495.48	6351.822	0.075046	0	93.57671	0	10423.27	6351.8	34.85054
96.06667	10495.48	6351.822	0.075046	0	92.7479	0.131017	10423.01	6351.8	34.85054
96.08334	10495.48	6351.822	0.075046	0	92.9551	0	10422.75	6351.8	34.85054
96.1	10495.48	6351.822	0.075046	0	92.3335	0.131017	10422.49	6351.8	34.85054
96.11667	10495.48	6351.822	0.075046	0	92.3335	0	10422.23	6351.8	34.85054
96.13333	10495.48	6351.822	0.075046	0	92.12631	0	10421.97	6351.8	34.85054
96.15	10495.47	6351.822	0.075046	0	92.7479	0.131017	10421.71	6351.8	34.85054
96.16666	10495.47	6351.822	0.075046	0	92.12631	0	10421.45	6351.8	34.85054
96.18333	10495.47	6351.822	0.075046	0	92.5407	0	10421.19	6351.8	34.85054
96.2	10495.47	6351.822	0.075046	0	92.12631	0	10420.93	6351.8	34.85054
96.21667	10495.47	6351.822	0.075046	0	92.3335	0	10420.67	6351.8	34.85054
96.23333	10495.47	6351.822	0.075046	0	92.12631	0	10420.41	6351.8	34.85054
96.25	10495.47	6351.822	0.075046	0	92.3335	0	10420.15	6351.8	34.85054
96.26667	10495.47	6351.822	0.075046	0	92.3335	0	10419.89	6351.8	34.85054

96.28333	10495.47	6351.822	0.075046	0	92.3335	0	10419.63	6351.8	34.85054
96.3	10495.47	6351.822	0.075046	0	92.12631	0	10419.38	6351.8	34.85054
96.31667	10495.47	6351.822	0.075046	0	92.3335	0	10419.12	6351.8	34.85054
96.33334	10495.47	6351.822	0.075046	0	92.3335	0	10418.86	6351.8	34.85054
96.35	10495.47	6351.822	0.075046	0	92.12631	0	10418.6	6351.8	34.85054
96.36667	10495.47	6351.822	0.075046	0	92.12631	0	10418.34	6351.8	34.85054
96.38333	10495.48	6351.822	0.075046	0	92.3335	0.131017	10418.08	6351.8	34.85054
96.4	10495.48	6351.822	0.075046	0	92.12631	0	10417.82	6351.8	34.85054
96.41666	10495.48	6351.822	0.075046	0	92.5407	0	10417.56	6351.8	34.85054
96.43333	10495.48	6351.822	0.075046	0	91.91911	0	10417.3	6351.8	34.85054
96.45	10495.48	6351.822	0.075046	0	92.3335	0	10417.04	6351.8	34.85054
96.46667	10495.48	6351.822	0.075046	0	92.5407	0	10416.78	6351.8	34.85054
96.48333	10495.48	6351.822	0.075046	0	92.12631	0	10416.52	6351.8	34.85054
96.5	10495.47	6351.822	0.075046	0	92.12631	0.131017	10416.26	6351.8	34.85054
96.51667	10495.47	6351.822	0.075046	0	92.3335	0	10416	6351.8	34.85054
96.53333	10495.47	6351.822	0.075046	0	92.12631	0	10415.74	6351.8	34.85054
96.55	10495.47	6351.822	0.075046	0	91.7119	0	10415.48	6351.8	34.85054
96.56667	10495.47	6351.822	0.075046	0	92.12631	0	10415.22	6351.8	34.85054
96.58334	10495.47	6351.822	0.075046	0.092081	92.3335	0	10414.96	6351.8	34.85054
96.6	10495.47	6351.822	0.075046	0	92.3335	0	10414.7	6351.8	34.85054
96.61667	10495.47	6351.822	0.075046	0	92.3335	0	10414.44	6351.8	34.85054
96.63333	10495.47	6351.822	0.075046	0	92.12631	0	10414.18	6351.8	34.85054
96.65	10495.47	6351.822	0.075046	0	92.12631	0	10413.92	6351.8	34.85054
96.66666	10495.47	6351.822	0.075046	0	92.5407	0	10413.66	6351.8	34.85054
96.68333	10495.47	6351.822	0.075046	0	92.12631	0	10413.4	6351.8	34.85054
96.7	10495.47	6351.822	0.075046	0	92.3335	0	10413.14	6351.8	34.85054
96.71667	10495.47	6351.822	0.075046	0	92.12631	0	10412.88	6351.8	34.85054
96.73333	10495.47	6351.822	0.075046	0	92.12631	0	10412.62	6351.8	34.71952
96.75	10495.47	6351.822	0.075046	0	92.5407	0	10412.36	6351.8	34.85054
96.76667	10495.47	6351.822	0.075046	0.138121	92.3335	0	10412.1	6351.8	34.85054
96.78333	10495.47	6351.822	0.075046	0	91.91911	0	10411.84	6351.8	34.85054
96.8	10495.47	6351.822	0.075046	0	92.12631	0	10411.58	6351.8	34.85054
96.81667	10495.47	6351.822	0.075046	0	91.91911	0	10411.32	6351.8	34.85054
96.83334	10495.47	6351.822	0.075046	0	92.12631	0	10411.06	6351.8	34.85054
96.85	10495.47	6351.822	0.075046	0	92.3335	0	10410.8	6351.8	34.85054
96.86667	10495.47	6351.822	0.075046	0	91.7119	0	10410.54	6351.8	34.85054
96.88333	10495.47	6351.822	0.075046	0	92.12631	0	10410.28	6351.8	34.85054
96.9	10495.47	6351.822	0.075046	0	92.3335	0	10410.02	6351.8	34.85054
96.91666	10495.47	6351.822	0.075046	0	92.3335	0	10409.76	6351.8	34.85054
96.93333	10495.47	6351.822	0.075046	0	92.5407	0	10409.5	6351.8	34.85054
96.95	10495.47	6351.822	0.075046	0	92.3335	0	10409.25	6351.8	34.85054
96.96667	10495.47	6351.822	0.075046	0	92.7479	0	10408.99	6351.8	34.85054
96.98333	10495.47	6351.822	0.075046	0	92.5407	0	10408.73	6351.8	34.85054
97	10495.47	6351.822	0.075046	0	92.5407	0	10408.47	6351.8	34.85054
97.01667	10495.47	6351.822	0.075046	0	92.7479	0	10408.21	6351.8	34.85054
97.03333	10495.47	6351.822	0.075046	0	92.12631	0	10407.95	6351.8	34.85054
97.05	10495.47	6351.822	0.075046	0	92.3335	0	10407.69	6351.8	34.85054

97.06667	10495.47	6351.822	0.075046	0	91.91911	0	10407.43	6351.8	34.85054
97.08334	10495.47	6351.822	0.075046	0	92.12631	0	10407.17	6351.8	34.85054
97.1	10495.47	6351.822	0.075046	0	92.3335	0	10406.91	6351.8	34.85054
97.11667	10495.47	6351.822	0.075046	0	92.3335	0	10406.65	6351.8	34.85054
97.13333	10495.47	6351.822	0.075046	0	92.3335	0	10406.39	6351.8	34.85054
97.15	10495.47	6351.822	0.075046	0	92.3335	0	10406.13	6351.8	34.85054
97.16666	10495.47	6351.822	0.075046	0	92.3335	0	10405.87	6351.8	34.85054
97.18333	10495.47	6351.822	0.075046	0	92.3335	0	10405.61	6351.8	34.85054
97.2	10495.47	6351.822	0.075046	0	91.5047	0	10405.35	6351.8	34.85054
97.21667	10495.47	6351.822	0.075046	0	92.9551	0	10405.09	6351.8	34.85054
97.23333	10495.47	6351.822	0.075046	0	92.5407	0	10404.83	6351.8	34.85054
97.25	10495.47	6351.822	0.075046	0	92.5407	0	10404.57	6351.8	34.85054
97.26667	10495.47	6351.822	0.075046	0	92.3335	0	10404.31	6351.8	34.85054
97.28333	10495.47	6351.822	0.075046	0	92.5407	0	10404.05	6351.8	34.85054
97.3	10495.47	6351.822	0.075046	0	92.3335	0	10403.79	6351.8	34.85054
97.31667	10495.47	6351.822	0.075046	0	92.7479	0	10403.53	6351.8	34.85054
97.33334	10495.47	6351.822	0.075046	0	92.5407	0	10403.27	6351.8	34.85054
97.35	10495.47	6351.822	0.075046	0	92.7479	0	10403.01	6351.8	34.85054
97.36667	10495.47	6351.822	0.075046	0	92.9551	0	10402.75	6351.8	34.85054
97.38333	10495.47	6351.822	0.075046	0.506445	92.3335	0	10402.49	6351.8	34.85054
97.4	10495.47	6351.822	0.075046	0	92.7479	0	10402.23	6351.8	34.85054
97.41666	10495.47	6351.822	0.075046	0.184162	92.3335	0	10401.97	6351.8	34.85054
97.43333	10495.47	6351.822	0.075046	0	92.5407	0	10401.71	6351.8	34.85054
97.45	10495.47	6351.822	0.075046	0	92.3335	0	10401.45	6351.8	34.85054
97.46667	10495.47	6351.822	0.075046	0	92.3335	0	10401.19	6351.8	34.85054
97.48333	10495.47	6351.822	0.075046	0	92.7479	0	10400.93	6351.8	34.85054
97.5	10495.47	6351.822	0.075046	0.04604	92.7479	0	10400.67	6351.8	34.71952
97.51667	10495.47	6351.822	0.075046	0	92.9551	0	10400.41	6351.8	34.85054
97.53333	10495.47	6351.822	0.075046	0	92.7479	0	10400.15	6351.8	34.85054
97.55	10495.47	6351.822	0.075046	0	92.7479	0	10399.89	6351.8	34.85054
97.56667	10495.47	6351.822	0.075046	0	92.9551	0	10399.63	6351.8	34.85054
97.58334	10495.47	6351.822	0.075046	0	93.1623	0	10399.38	6351.8	34.85054
97.6	10495.47	6351.822	0.075046	0	92.7479	0	10399.12	6351.8	34.85054
97.61667	10495.47	6351.822	0.075046	0	93.1623	0	10398.86	6351.8	34.85054
97.63333	10495.47	6351.822	0.075046	0	92.9551	0	10398.6	6351.8	34.85054
97.65	10495.47	6351.822	0.075046	0	92.7479	0	10398.34	6351.8	34.85054
97.66666	10495.47	6351.822	0.075046	0	93.1623	0	10398.08	6351.8	34.85054
97.68333	10495.47	6351.822	0.075046	0	93.1623	0	10397.82	6351.8	34.85054
97.7	10495.47	6351.822	0.075046	0	92.9551	0	10397.56	6351.8	34.85054
97.71667	10495.47	6351.822	0.075046	0	92.9551	0	10397.3	6351.8	34.85054
97.73333	10495.47	6351.822	0.075046	0	92.9551	0	10397.04	6351.8	34.85054
97.75	10495.47	6351.822	0.075046	0	92.7479	0	10396.78	6351.8	34.85054
97.76667	10495.47	6351.822	0.075046	0	92.9551	0	10396.52	6351.8	34.85054
97.78333	10495.47	6351.822	0.075046	0	92.9551	0	10396.26	6351.8	34.85054
97.8	10495.47	6351.822	0.075046	0	93.1623	0	10396	6351.8	34.85054
97.81667	10495.47	6351.822	0.075046	0	92.7479	0	10395.74	6351.8	34.85054
97.83334	10495.47	6351.822	0.075046	0	92.9551	0	10395.48	6351.8	34.85054

97.85	10495.47	6351.822	0.075046	0	92.12631	0	10395.22	6351.8	34.85054
97.86667	10495.47	6351.822	0.075046	0	93.1623	0	10394.96	6351.8	34.85054
97.88333	10495.47	6351.822	0.075046	0	92.9551	0	10394.7	6351.8	34.85054
97.9	10495.47	6351.822	0.075046	0	92.9551	0	10394.44	6351.8	34.85054
97.91666	10495.47	6351.822	0.075046	0	92.9551	0	10394.18	6351.8	34.85054
97.93333	10495.47	6351.822	0.075046	0	92.9551	0	10393.92	6351.8	34.85054
97.95	10495.47	6351.822	0.075046	0	93.3695	0	10393.66	6351.8	34.85054
97.96667	10495.47	6351.822	0.075046	0	93.1623	0	10393.4	6351.8	34.85054
97.98333	10495.47	6351.822	0.075046	0	92.9551	0	10393.14	6351.8	34.85054
98	10495.47	6351.822	0.075046	0	93.1623	0	10392.88	6351.8	34.85054
98.01667	10495.47	6351.822	0.075046	0	93.1623	0	10392.62	6351.8	34.85054
98.03333	10495.47	6351.822	0.075046	0	92.7479	0	10392.36	6351.8	34.85054
98.05	10495.47	6351.822	0.075046	0.230202	93.57671	0	10392.1	6351.8	34.85054
98.06667	10495.47	6351.822	0.075046	1.243093	93.1623	0	10391.84	6351.8	34.85054
98.08334	10495.47	6351.822	0.075046	0	93.1623	0	10391.58	6351.8	34.85054
98.1	10495.47	6351.822	0.075046	0	93.57671	0	10391.32	6351.8	34.85054
98.11667	10495.47	6351.822	0.075046	0	93.3695	0	10391.06	6351.8	34.85054
98.13333	10495.47	6351.822	0.075046	0	93.3695	0	10390.8	6351.8	34.85054
98.15	10495.47	6351.822	0.075046	0	93.78391	0	10390.54	6351.8	34.85054
98.16666	10495.47	6351.822	0.075046	0	93.9911	0	10390.28	6351.8	34.85054
98.18333	10495.47	6351.822	0.075046	0	94.4055	0	10390.02	6351.8	34.85054
98.2	10495.47	6351.822	0.075046	0	93.9911	0	10389.76	6351.8	34.85054
98.21667	10495.47	6351.822	0.075046	0	94.4055	0	10389.5	6351.8	34.85054
98.23333	10495.47	6351.822	0.075046	0	95.23431	0	10389.24	6351.8	34.85054
98.25	10495.47	6351.822	0.075046	0	95.0271	0	10388.98	6351.8	34.85054
98.26667	10495.47	6351.822	0.075046	0	94.8199	0	10388.73	6351.8	34.71952
98.28333	10495.47	6351.822	0.075046	0	95.23431	0	10388.47	6351.8	34.85054
98.3	10495.47	6351.822	0.075046	0	95.23431	0	10388.21	6351.8	34.85054
98.31667	10495.47	6351.822	0.075046	0	95.44151	0	10387.95	6351.8	34.85054
98.33334	10495.47	6351.822	0.075046	0	95.44151	0	10387.69	6351.8	34.85054
98.35	10495.47	6351.822	0.075046	0	95.23431	0	10387.43	6351.8	34.85054
98.36667	10495.47	6351.822	0.075046	0	95.0271	0	10387.17	6351.8	34.85054
98.38333	10495.47	6351.822	0.075046	0.04604	95.64871	0	10386.91	6351.8	34.85054
98.4	10495.47	6351.822	0.075046	0.04604	95.8559	0	10386.65	6351.8	34.85054
98.41666	10495.47	6351.822	0.075046	0	95.44151	0	10386.39	6351.8	34.85054
98.43333	10495.47	6351.822	0.075046	0	95.44151	0	10386.13	6351.8	34.85054
98.45	10495.47	6351.822	0.075046	0	95.44151	0	10385.87	6351.8	34.85054
98.46667	10495.47	6351.822	0.075046	0	95.44151	0	10385.61	6351.8	34.85054
98.48333	10495.47	6351.822	0.075046	0	95.44151	0	10385.35	6351.8	34.85054
98.5	10495.47	6351.822	0.075046	0	94.8199	0	10385.09	6351.8	34.85054
98.51667	10495.47	6351.822	0.075046	0	95.44151	0	10384.83	6351.8	34.85054
98.53333	10495.47	6351.822	0.075046	0	95.23431	0	10384.57	6351.8	34.85054
98.55	10495.47	6351.822	0.075046	0	95.44151	0	10384.31	6351.8	34.85054
98.56667	10495.47	6351.822	0.075046	0	95.23431	0	10384.05	6351.8	34.85054
98.58334	10495.47	6351.822	0.075046	0	95.44151	0	10383.79	6351.8	34.85054
98.6	10495.47	6351.822	0.075046	0	95.44151	0	10383.53	6351.8	34.85054
98.61667	10495.47	6351.822	0.075046	0	95.44151	0	10383.27	6351.8	34.85054

98.63333	10495.47	6351.822	0.075046	0	95.23431	0	10383.01	6351.8	34.85054
98.65	10495.47	6351.822	0.075046	0.04604	95.23431	0	10382.75	6351.8	34.85054
98.66666	10495.47	6351.822	0.075046	0	95.23431	0	10382.49	6351.8	34.85054
98.68333	10495.47	6351.822	0.075046	0	95.23431	0	10382.23	6351.8	34.85054
98.7	10495.47	6351.822	0.075046	0.04604	95.44151	0	10381.97	6351.8	34.85054
98.71667	10495.47	6351.822	0.075046	0	95.44151	0	10381.71	6351.8	34.85054
98.73333	10495.47	6351.822	0.075046	0	95.44151	0	10381.45	6351.8	34.85054
98.75	10495.47	6351.822	0.075046	0	95.23431	0	10381.19	6351.8	34.85054
98.76667	10495.47	6351.822	0.075046	0	95.44151	0	10380.93	6351.8	34.85054
98.78333	10495.47	6351.822	0.075046	0	95.0271	0	10380.67	6351.8	34.85054
98.8	10495.47	6351.822	0.075046	0	95.23431	0	10380.41	6351.8	34.85054
98.81667	10495.47	6351.822	0.075046	0	95.23431	0	10380.15	6351.8	34.85054
98.83334	10495.47	6351.822	0.075046	0	95.23431	0	10379.89	6351.8	34.85054
98.85	10495.47	6351.822	0.075046	0	95.23431	0	10379.63	6351.8	34.85054
98.86667	10495.47	6351.822	0.075046	0	95.0271	0	10379.37	6351.8	34.85054
98.88333	10495.47	6351.822	0.075046	0	95.0271	0	10379.11	6351.8	34.85054
98.9	10495.47	6351.822	0.075046	0	95.44151	0	10378.85	6351.8	34.85054
98.91666	10495.47	6351.822	0.075046	0	95.23431	0	10378.59	6351.8	34.85054
98.93333	10495.47	6351.822	0.075046	0	95.23431	0	10378.33	6351.8	34.85054
98.95	10495.47	6351.822	0.075046	0	95.23431	0	10378.08	6351.8	34.85054
98.96667	10495.47	6351.822	0.075046	0	95.23431	0	10377.82	6351.8	34.85054
98.98333	10495.47	6351.822	0.075046	0	95.23431	0	10377.56	6351.8	34.85054
99	10495.47	6351.822	0.075046	0	95.23431	0	10377.3	6351.8	34.85054
99.01667	10495.47	6351.822	0.075046	0	95.44151	0	10377.04	6351.8	34.85054
99.03333	10495.47	6351.822	0.075046	0	95.23431	0	10376.78	6351.8	34.85054
99.05	10495.47	6351.822	0.075046	0	95.44151	0	10376.52	6351.8	34.71952
99.06667	10495.47	6351.822	0.075046	0	93.78391	0	10376.26	6351.8	34.85054
99.08334	10495.47	6351.822	0.075046	0	95.23431	0	10376	6351.8	34.85054
99.1	10495.47	6351.822	0.075046	0	95.23431	0	10375.74	6351.8	34.85054
99.11667	10495.47	6351.822	0.075046	0	95.23431	0	10375.48	6351.8	34.85054
99.13333	10495.47	6351.822	0.075046	0	95.23431	0	10375.22	6351.8	34.85054
99.15	10495.47	6351.822	0.075046	0	95.23431	0	10374.96	6351.8	34.85054
99.16666	10495.47	6351.822	0.075046	0	95.23431	0	10374.7	6351.8	34.85054
99.18333	10495.47	6351.822	0.075046	0	95.23431	0	10374.44	6351.8	34.85054
99.2	10495.47	6351.822	0.075046	0	95.23431	0	10374.18	6351.8	34.85054
99.21667	10495.47	6351.822	0.075046	0	94.8199	0	10373.92	6351.8	34.85054
99.23333	10495.47	6351.822	0.075046	0	95.44151	0	10373.66	6351.8	34.85054
99.25	10495.47	6351.822	0.075046	0	95.23431	0	10373.4	6351.8	34.85054
99.26667	10495.47	6351.822	0.075046	0	95.23431	0	10373.14	6351.8	34.85054
99.28333	10495.47	6351.822	0.075046	0	95.23431	0	10372.88	6351.8	34.85054
99.3	10495.47	6351.822	0.075046	0	95.44151	0	10372.62	6351.8	34.85054
99.31667	10495.47	6351.822	0.075046	0	95.23431	0	10372.36	6351.8	34.85054
99.33334	10495.47	6351.822	0.075046	0	95.23431	0	10372.1	6351.8	34.85054
99.35	10495.47	6351.822	0.075046	0	95.44151	0	10371.84	6351.8	34.85054
99.36667	10495.47	6351.822	0.075046	0.092081	95.23431	0	10371.58	6351.8	34.85054
99.38333	10495.47	6351.822	0.075046	0	95.64871	0	10371.32	6351.8	34.85054
99.4	10495.47	6351.822	0.075046	0	95.0271	0	10371.06	6351.8	34.85054

99.41666	10495.47	6351.822	0.075046	0	95.23431	0	10370.8	6351.8	34.85054
99.43333	10495.47	6351.822	0.075046	0	95.23431	0	10370.54	6351.8	34.85054
99.45	10495.47	6351.822	0.075046	0	95.44151	0	10370.28	6351.8	34.85054
99.46667	10495.47	6351.822	0.075046	0	95.23431	0	10370.02	6351.8	34.85054
99.48333	10495.47	6351.822	0.075046	0	95.23431	0	10369.76	6351.8	34.85054
99.5	10495.47	6351.822	0.075046	0	95.44151	0	10369.5	6351.8	34.85054
99.51667	10495.47	6351.822	0.075046	0	94.8199	0	10369.24	6351.8	34.85054
99.53333	10495.47	6351.822	0.075046	0	95.23431	0	10368.98	6351.8	34.85054
99.55	10495.47	6351.822	0.075046	0	95.0271	0	10368.72	6351.8	34.85054
99.56667	10495.47	6351.822	0.075046	0	94.6127	0	10368.46	6351.8	34.85054
99.58334	10495.47	6351.822	0.075046	0.04604	94.8199	0	10368.21	6351.8	34.85054
99.6	10495.47	6351.822	0.075046	0	94.8199	0	10367.95	6351.8	34.85054
99.61667	10495.47	6351.822	0.075046	0	94.6127	0	10367.69	6351.8	34.85054
99.63333	10495.47	6351.822	0.075046	0	94.4055	0	10367.43	6351.8	34.85054
99.65	10495.47	6351.822	0.075046	0	95.0271	0	10367.17	6351.8	34.85054
99.66666	10495.47	6351.822	0.075046	0	94.1983	0	10366.91	6351.8	34.85054
99.68333	10495.47	6351.822	0.075046	0	94.6127	0	10366.65	6351.8	34.85054
99.7	10495.47	6351.822	0.075046	0	94.4055	0	10366.39	6351.8	34.85054
99.71667	10495.47	6351.822	0.075046	0	93.9911	0	10366.13	6351.8	34.85054
99.73333	10495.47	6351.822	0.075046	0	93.78391	0	10365.87	6351.8	34.85054
99.75	10495.47	6351.822	0.075046	0	94.1983	0	10365.61	6351.8	34.85054
99.76667	10495.47	6351.822	0.075046	0	93.9911	0	10365.35	6351.8	34.85054
99.78333	10495.47	6351.822	0.075046	0	94.1983	0	10365.09	6351.8	34.85054
99.8	10495.47	6351.822	0.075046	0	93.57671	0	10364.83	6351.8	34.85054
99.81667	10495.47	6351.822	0.075046	0	93.78391	0	10364.57	6351.8	34.71952
99.83334	10495.47	6351.822	0.075046	0	93.57671	0	10364.31	6351.8	34.85054
99.85	10495.47	6351.822	0.075046	0	93.57671	0	10364.05	6351.8	34.85054
99.86667	10495.47	6351.822	0.075046	0.04604	93.78391	0	10363.79	6351.8	34.85054
99.88333	10495.47	6351.822	0.075046	0	93.57671	0	10363.53	6351.8	34.85054
99.9	10495.47	6351.822	0.075046	0	93.78391	0	10363.27	6351.8	34.85054
99.91666	10495.47	6351.822	0.075046	0	93.9911	0	10363.01	6351.8	34.85054
99.93333	10495.47	6351.822	0.075046	0	93.9911	0	10362.75	6351.8	34.85054
99.95	10495.47	6351.822	0.075046	0	93.78391	0	10362.49	6351.8	34.85054
99.96667	10495.47	6351.822	0.075046	0	93.57671	0	10362.23	6351.8	34.85054
99.98333	10495.47	6351.822	0.075046	0	93.3695	0	10361.97	6351.8	34.85054
100	10495.47	6351.822	0.075046	0	93.3695	0	10361.71	6351.8	34.85054
100.0167	10495.47	6351.822	0.075046	0	93.78391	0	10361.45	6351.8	34.85054
100.0333	10495.47	6351.822	0.075046	0	93.57671	0	10361.19	6351.8	34.85054
100.05	10495.47	6351.822	0.075046	0.552486	93.1623	0	10360.93	6351.8	34.85054
100.0667	10495.47	6351.822	0.075046	0	93.3695	0	10360.67	6351.8	34.85054
100.0833	10495.47	6351.822	0.075046	0	93.1623	0	10360.41	6351.8	34.85054
100.1	10495.47	6351.822	0.075046	0	92.7479	0	10360.15	6351.8	34.85054
100.1167	10495.47	6351.822	0.075046	0	92.3335	0	10359.89	6351.8	34.85054
100.1333	10495.47	6351.822	0.075046	0	91.2975	0	10359.63	6351.8	34.85054
100.15	10495.47	6351.822	0.075046	0	89.8471	0	10359.37	6351.8	34.85054
100.1667	10495.47	6351.822	0.075046	0	88.60391	0	10359.11	6351.8	34.85054
100.1833	10495.47	6351.822	0.075046	0	87.7751	0	10358.85	6351.8	34.85054

100.2	10495.47	6351.822	0.075046	0	87.5679	0	10358.59	6351.8	34.85054
100.2167	10495.47	6351.822	0.075046	0	85.08151	0	10358.33	6351.8	34.85054
100.2333	10495.47	6351.822	0.075046	0	83.21671	0	10358.08	6351.8	34.85054
100.25	10495.47	6351.822	0.075046	0	81.9735	0	10357.82	6351.8	34.85054
100.2667	10495.47	6351.822	0.075046	0	79.2799	0	10357.56	6351.8	34.85054
100.2833	10495.47	6351.822	0.075046	0	74.3071	0	10357.3	6351.8	34.85054
100.3	10495.47	6351.822	0.075046	0	70.99191	0	10357.04	6351.8	34.85054
100.3167	10495.47	6351.822	0.075046	0	67.46951	0	10356.78	6351.8	34.85054
100.3333	10495.47	6351.822	0.075046	0	64.15431	0	10356.52	6351.8	34.85054
100.35	10495.47	6351.822	0.075046	0	56.0735	0	10356.26	6351.8	34.85054
100.3667	10495.47	6351.822	0.075046	0	50.8935	0	10356	6351.8	34.85054
100.3833	10495.47	6351.822	0.075046	0	46.9567	0	10355.74	6351.8	34.85054
100.4	10495.47	6351.822	0.075046	0	41.1551	0	10355.48	6351.8	34.85054
100.4167	10495.47	6351.822	0.075046	0	31.8311	0	10355.22	6351.8	34.85054
100.4333	10495.47	6351.822	0.075046	0	27.8943	0	10354.96	6351.8	34.85054
100.45	10495.47	6351.822	0.075046	0	24.1647	0	10354.7	6351.8	34.85054
100.4667	10495.47	6351.822	0.075046	0	21.0567	0	10354.44	6351.8	34.85054
100.4833	10495.47	6351.822	0.075046	0	17.1199	0	10354.18	6351.8	34.85054
100.5	10495.47	6351.822	0.075046	0	14.6335	0	10353.92	6351.8	34.85054
100.5167	10495.47	6351.822	0.075046	0.04604	12.9759	0	10353.66	6351.8	34.85054
100.5333	10495.47	6351.822	0.075046	0	11.1111	0	10353.4	6351.8	34.85054
100.55	10495.47	6351.822	0.075046	0	9.039101	0	10353.14	6351.8	34.85054
100.5667	10495.47	6351.822	0.075046	0	8.0031	0	10352.88	6351.8	34.85054
100.5833	10495.47	6351.822	0.075046	0	6.7599	0	10352.62	6351.8	34.71952
100.6	10495.47	6351.822	0.075046	0	5.1023	0	10352.36	6351.8	34.85054
100.6167	10495.47	6351.822	0.075046	0	2.2015	0	10352.1	6351.8	34.85054
100.6333	10495.47	6351.822	0.075046	0.04604	0.1295	0	10351.84	6351.8	34.85054
100.65	10495.47	6351.822	0.075046	0	0	0	10351.58	6351.8	34.85054
100.6667	10495.47	6351.822	0.075046	0	0	0	10351.32	6351.8	34.85054
100.6833	10495.47	6351.822	0.075046	0	0	0	10351.06	6351.8	34.85054
100.7	10495.47	6351.822	0.075046	0	0	0	10350.8	6351.8	34.85054
100.7167	10495.47	6351.822	0.075046	0	0	0	10350.54	6351.8	34.85054
100.7333	10495.47	6351.822	0.075046	0	0	0	10350.28	6351.8	34.85054
100.75	10495.47	6351.822	0.075046	0	0	0	10350.02	6351.8	34.85054
100.7667	10495.47	6351.822	0.075046	0	0	0	10349.76	6351.8	34.85054
100.7833	10495.47	6351.822	0.075046	0	0	0	10349.5	6351.8	34.85054
100.8	10495.47	6351.822	0.075046	0	0	0	10349.24	6351.8	34.85054
100.8167	10495.47	6351.822	0.075046	0	0	0	10348.98	6351.8	34.85054
100.8333	10495.47	6351.822	0.075046	0	0	0	10348.72	6351.8	34.85054
100.85	10495.47	6351.822	0.075046	0	0	0	10348.46	6351.8	34.85054
100.8667	10495.47	6351.822	0.075046	0	0	0	10348.21	6351.8	34.85054
100.8833	10495.47	6351.822	0.075046	0	0	0	10347.95	6351.8	34.85054
100.9	10495.47	6351.822	0.075046	0	0	0	10347.69	6351.8	34.85054
100.9167	10495.47	6351.822	0.075046	0	0	0	10347.43	6351.8	34.85054
100.9333	10495.47	6351.822	0.075046	0	0	0	10347.17	6351.8	34.85054
100.95	10495.47	6351.822	0.075046	0	0	0	10346.91	6351.8	34.85054
100.9667	10495.47	6351.822	0.075046	0	0	0	10346.65	6351.8	34.85054

100.9833	10495.47	6351.822	0.075046	0	0	0	10346.39	6351.8	34.85054
101	10495.47	6351.822	0.075046	0	0	0	10346.13	6351.8	34.85054
101.0167	10495.47	6351.822	0.075046	0.322283	0	0	10345.87	6351.8	34.85054
101.0333	10495.47	6351.822	0.075046	0	0	0	10345.61	6351.8	34.85054
101.05	10495.47	6351.822	0.075046	0	0	0	10345.35	6351.8	34.85054
101.0667	10495.47	6351.822	0.075046	0	0	0	10345.09	6351.8	34.85054
101.0833	10495.47	6351.822	0.075046	0	0	0	10344.83	6351.8	34.85054
101.1	10495.47	6351.822	0.075046	0	0	0	10344.57	6351.8	34.85054
101.1167	10495.47	6351.822	0.075046	0	0	0	10344.31	6351.8	34.85054
101.1333	10495.47	6351.822	0.075046	0	0	0	10344.05	6351.8	34.85054
101.15	10495.47	6351.822	0.075046	0	0	0	10343.79	6351.8	34.85054
101.1667	10495.47	6351.822	0.075046	0	0	0	10343.53	6351.8	34.85054
101.1833	10495.47	6351.822	0.075046	0	0	0	10343.27	6351.8	34.85054
101.2	10495.47	6351.822	0.075046	0	0	0	10343.01	6351.8	34.85054
101.2167	10495.47	6351.822	0.075046	0	0	0	10342.75	6351.8	34.85054
101.2333	10495.47	6351.822	0.075046	0	0	0	10342.49	6351.8	34.85054
101.25	10495.47	6351.822	0.075046	0	0	0	10342.23	6351.8	34.85054
101.2667	10495.47	6351.822	0.075046	0	0	0	10341.97	6351.8	34.85054
101.2833	10495.47	6351.822	0.075046	0.04604	0	0	10341.71	6351.8	34.85054
101.3	10495.47	6351.822	0.075046	0	0	0	10341.45	6351.8	34.85054
101.3167	10495.47	6351.822	0.075046	0	0	0	10341.19	6351.8	34.85054
101.3333	10495.47	6351.822	0.075046	0	0	0	10340.93	6351.8	34.85054
101.35	10495.47	6351.822	0.075046	0	0	0	10340.67	6351.8	34.71952
101.3667	10495.47	6351.822	0.075046	0	0	0	10340.41	6351.8	34.85054
101.3833	10495.47	6351.822	0.075046	0	0	0	10340.15	6351.8	34.85054
101.4	10495.47	6351.822	0.075046	0	0	0	10339.89	6351.8	34.85054
101.4167	10495.47	6351.822	0.075046	0	0	0	10339.63	6351.8	34.85054
101.4333	10495.47	6351.822	0.075046	0.04604	0	0	10339.37	6351.8	34.85054
101.45	10495.47	6351.822	0.075046	0	0	0	10339.11	6351.8	34.85054
101.4667	10495.47	6351.822	0.075046	0.04604	0	0	10338.85	6351.8	34.85054
101.4833	10495.47	6351.822	0.075046	0	0	0	10338.59	6351.8	34.85054
101.5	10495.47	6351.822	0.075046	0	0	0	10338.33	6351.8	34.85054
101.5167	10495.47	6351.822	0.075046	0	0	0	10338.08	6351.8	34.85054
101.5333	10495.47	6351.822	0.075046	0	0	0	10337.82	6351.8	34.85054
101.55	10495.47	6351.822	0.075046	0	0	0	10337.56	6351.8	34.85054
101.5667	10495.47	6351.822	0.075046	0	0	0	10337.3	6351.8	34.85054
101.5833	10495.47	6351.822	0.075046	0	0	0	10337.04	6351.8	34.85054
101.6	10495.47	6351.822	0.075046	0	0	0	10336.78	6351.8	34.85054
101.6167	10495.47	6351.822	0.075046	0	0	0	10336.52	6351.8	34.85054
101.6333	10495.47	6351.822	0.075046	0	0	0	10336.26	6351.8	34.85054
101.65	10495.47	6351.822	0.075046	0	0	0	10336	6351.8	34.85054
101.6667	10495.47	6351.822	0.075046	0.276243	0	0	10335.74	6351.8	34.85054
101.6833	10495.47	6351.822	0.075046	0	0	0	10335.48	6351.8	34.85054
101.7	10495.47	6351.822	0.075046	0	0	0	10335.22	6351.8	34.85054
101.7167	10495.47	6351.822	0.075046	0	0	0	10334.96	6351.8	34.85054
101.7333	10495.47	6351.822	0.075046	0	0	0	10334.7	6351.8	34.85054
101.75	10495.47	6351.822	0.075046	0	0	0	10334.44	6351.8	34.85054

101.7667	10495.47	6351.822	0.075046	0	0	0	10334.18	6351.8	34.85054
101.7833	10495.47	6351.822	0.075046	0	0	0	10333.92	6351.8	34.85054
101.8	10495.47	6351.822	0.075046	0	0	0	10333.66	6351.8	34.85054
101.8167	10495.47	6351.822	0.075046	0	0	0	10333.4	6351.8	34.85054
101.8333	10495.47	6351.822	0.075046	0	0	0	10333.14	6351.8	34.85054
101.85	10495.47	6351.822	0.075046	0	0	0	10332.88	6351.8	34.85054
101.8667	10495.47	6351.822	0.075046	0	0	0	10332.62	6351.8	34.85054
101.8833	10495.47	6351.822	0.075046	0	0	0	10332.36	6351.8	34.85054
101.9	10495.47	6351.822	0.075046	0	0	0	10332.1	6351.8	34.85054
101.9167	10495.47	6351.822	0.075046	0	0	0	10331.84	6351.8	34.85054
101.9333	10495.47	6351.822	0.075046	0	0	0	10331.58	6351.8	34.85054
101.95	10495.47	6351.822	0.075046	0	0	0	10331.32	6351.8	34.85054
101.9667	10495.47	6351.822	0.075046	0	0	0	10331.06	6351.8	34.85054
0	0	0	0	0	0	0	0	0	0

Table B2: Horizontal visibility blockage scenario sample data output

User Information
Subject#:70
Name:abir
Gender:f
Age:25
Scenario:horizontal_ltv

sim_time	x_position	y_position	steering _input	accelerator _input	brake _input	speed	vechicle1 _x	vechicle 1_y	vechicle1 _speed	vechicle 2_x	vechicle2 _y	vechicle2_ speed
13.03333	12538.11	6351	-0.1129	0.690607	0	0	11103	6350	0	10400	6348	0
13.05	12538.11	6351	-0.1129	0.874769	0	0	11103	6350	0	10400	6348	0
13.06667	12538.11	6351	-0.1129	0.782688	0	0	11103	6350	0	10400	6348	0
13.08333	12538.11	6351	-0.1129	0.782688	0	0	11103	6350	0	10400	6348	0
13.1	12538.11	6351	-0.1129	0.828729	0	0	11103	6350	0	10400	6348	0
13.11667	12538.11	6351	-0.1129	0.782688	0	0	11103	6350	0	10400	6348	0
13.13333	12538.11	6351	-0.1129	0.874769	0	0	11103	6350	0	10400	6348	0
13.15	12538.11	6351	-0.1129	0.874769	0	0	11103	6350	0	10400	6348	0
13.16667	12538.11	6351	-0.1129	0.874769	0	0	11103	6350	0	10400	6348	0
13.18333	12538.11	6351	-0.1129	0.874769	0	0	11103	6350	0	10400	6348	0
13.2	12538.11	6351	-0.1129	0.828729	0	0	11103	6350	0	10400	6348	0
13.21667	12538.11	6351	-0.1129	0.96685	0	0	11103	6350	0	10400	6348	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8167	10592.9	6352.318	-0.0082	0.690607	100	0	10587.4	6351.8	0	10585.1	6373.07	0
124.8333	10592.75	6352.317	-0.0082	0.782688	0	19.92	10587.4	6351.8	0	10585	6373.33	34.89122
124.85	10592.6	6352.316	-0.0082	0.828729	0	19.65	10587.4	6351.8	0	10585	6373.59	34.89122
124.8667	10592.46	6352.315	-0.0082	1.104972	0	19.52	10587.4	6351.8	0	10585	6373.85	34.87621
124.8833	10592.31	6352.314	-0.0082	0.598526	0	19.39	10587.4	6351.8	0	10585	6374.11	34.9413
124.9	10592.17	6352.313	-0.0082	0.782688	0	19.26	10587.4	6351.8	0	10584.9	6374.36	34.86168
124.9167	10592.03	6352.313	-0.0082	0.736648	0	19.26	10587.4	6351.8	0	10584.9	6374.62	34.9268
124.9333	10591.88	6352.312	-0.0082	0.782688	0	19.26	10587.4	6351.8	0	10584.9	6374.88	34.84765
124.95	10591.74	6352.311	-0.0082	0.828729	0	19	10587.4	6351.8	0	10584.8	6375.14	34.91279
124.9667	10591.6	6352.31	-0.0082	0.690607	0	19	10587.4	6351.8	0	10584.8	6375.4	34.91279
124.9833	10591.46	6352.31	-0.0082	0.874769	0	18.87	10587.4	6351.8	0	10584.8	6375.66	34.8341

125	10591.32	6352.309	-0.0082	0.782688	0	18.74	10587.4	6351.8	0	10584.8	6375.92	34.89927
125.0167	10591.18	6352.308	-0.0082	0.96685	0	18.6	10587.4	6351.8	0	10584.7	6376.17	34.89927
125.0333	10591.04	6352.307	-0.0082	0.736648	0	18.6	10587.4	6351.8	0	10584.7	6376.43	34.88623
125.05	10590.91	6352.306	-0.0082	0.782688	0	18.34	10587.4	6351.8	0	10584.7	6376.69	34.95143
125.0667	10590.77	6352.306	-0.0082	0.736648	0	18.34	10587.4	6351.8	0	10584.7	6376.95	34.87368
125.0833	10590.63	6352.305	-0.0082	0.828729	0	18.08	10587.4	6351.8	0	10584.6	6377.21	34.87368
125.1	10590.5	6352.304	-0.0082	0.782688	0	18.08	10587.4	6351.8	0	10584.6	6377.47	34.87368
125.1167	10590.37	6352.303	-0.0082	0.828729	0	17.95	10587.4	6351.8	0	10584.6	6377.73	34.92687
125.1333	10590.23	6352.302	-0.0082	0.782688	0	17.82	10587.4	6351.8	0	10584.6	6377.99	34.86162
125.15	10590.1	6352.302	-0.0082	0.782688	0	17.56	10587.4	6351.8	0	10584.5	6378.25	34.91531
125.1667	10589.97	6352.301	-0.0082	0.782688	0	17.56	10587.4	6351.8	0	10584.5	6378.51	34.92687
125.1833	10589.84	6352.3	-0.0082	1.197052	0	17.43	10587.4	6351.8	0	10584.5	6378.76	34.85005
125.2	10589.71	6352.299	-0.0082	0.736648	0	17.29	10587.4	6351.8	0	10584.5	6379.02	34.90425
125.2167	10589.58	6352.299	-0.0082	0.690607	0	17.16	10587.4	6351.8	0	10584.5	6379.28	34.90425
125.2333	10589.46	6352.298	-0.0082	0.736648	0	17.03	10587.4	6351.8	0	10584.4	6379.54	34.90425
125.25	10589.33	6352.297	-0.0082	0.828729	0	17.03	10587.4	6351.8	0	10584.4	6379.8	34.83897
125.2667	10589.21	6352.296	-0.0082	0.736648	0	16.77	10587.4	6351.8	0	10584.4	6380.06	34.89367
125.2833	10589.08	6352.296	-0.0082	0.782688	0	16.64	10587.4	6351.8	0	10584.4	6380.32	34.89367
125.3	10588.96	6352.295	-0.0082	0.782688	0	16.64	10587.4	6351.8	0	10584.3	6380.58	34.89367
125.3167	10588.84	6352.294	-0.0082	0.828729	0	16.38	10587.4	6351.8	0	10584.3	6380.84	34.88359
125.3333	10588.71	6352.294	-0.0082	0.690607	0	16.38	10587.4	6351.8	0	10584.3	6381.1	34.94891
125.35	10588.59	6352.293	-0.0082	0.874769	0	16.12	10587.4	6351.8	0	10584.3	6381.36	34.88359
125.3667	10588.47	6352.292	-0.0082	1.104972	0	16.12	10587.4	6351.8	0	10584.3	6381.62	34.87399
125.3833	10588.35	6352.292	-0.0082	0.736648	0	15.98	10587.4	6351.8	0	10584.3	6381.88	34.88359
125.4	10588.24	6352.292	-0.0082	0.782688	0	15.85	10587.4	6351.8	0	10584.2	6382.14	34.93024
125.4167	10588.12	6352.291	-0.0082	0.782688	0	15.72	10587.4	6351.8	0	10584.2	6382.4	34.87399
125.4333	10588	6352.29	-0.0082	0.690607	0	15.72	10587.4	6351.8	0	10584.2	6382.65	34.86488
125.45	10587.89	6352.29	-0.0082	0.782688	0	15.46	10587.4	6351.8	0	10584.2	6382.91	34.93024
125.4667	10587.77	6352.289	-0.0082	0.92081	0	15.46	10587.4	6351.8	0	10584.2	6383.17	34.86488
125.4833	10587.66	6352.289	-0.0082	0.598526	0	15.33	10587.4	6351.8	0	10584.1	6383.43	34.93024
125.5	10587.54	6352.288	-0.0082	0.782688	0	15.2	10587.4	6351.8	0	10584.1	6383.69	34.85627
125.5167	10587.43	6352.287	-0.0082	0.828729	0	15.2	10587.4	6351.8	0	10584.1	6383.95	34.92164
125.5333	10587.32	6352.287	-0.0082	0.782688	0	14.94	10587.4	6351.8	0	10584.1	6384.21	34.85627
125.55	10587.21	6352.286	-0.0082	0.782688	0	14.94	10587.4	6351.8	0	10584.1	6384.47	34.91353
125.5667	10587.1	6352.286	-0.0082	0.828729	0	14.67	10587.4	6351.8	0	10584.1	6384.73	34.85627
125.5833	10586.99	6352.285	-0.0082	0.874769	0	14.67	10587.4	6351.8	0	10584	6384.99	34.91353
125.6	10586.88	6352.285	-0.0082	0.828729	0	14.54	10587.4	6351.8	0	10584	6385.25	34.91353
125.6167	10586.77	6352.284	-0.0082	0.782688	0	14.41	10587.4	6351.8	0	10584	6385.51	34.90591
125.6333	10586.67	6352.284	-0.0082	0.690607	0	14.28	10587.4	6351.8	0	10584	6385.77	34.84814
125.65	10586.56	6352.283	-0.0082	0.828729	0	14.28	10587.4	6351.8	0	10584	6386.03	34.90591
125.6667	10586.46	6352.283	-0.0082	0.782688	0	14.02	10587.4	6351.8	0	10584	6386.29	34.90591
125.6833	10586.35	6352.282	-0.0082	0.92081	0	13.89	10587.4	6351.8	0	10584	6386.55	34.89878
125.7	10586.25	6352.282	-0.0082	0.874769	0	13.89	10587.4	6351.8	0	10583.9	6386.81	34.90591
125.7167	10586.15	6352.281	-0.0082	0.736648	0	13.76	10587.4	6351.8	0	10583.9	6387.07	34.83336
125.7333	10586.05	6352.281	-0.0082	0.736648	0	13.49	10587.4	6351.8	0	10583.9	6387.33	34.89878
125.75	10585.95	6352.28	-0.0082	0.782688	0	13.49	10587.4	6351.8	0	10583.9	6387.59	34.89878
125.7667	10585.85	6352.28	-0.0082	0.690607	0	13.36	10587.4	6351.8	0	10583.9	6387.85	34.89878
125.7833	10585.75	6352.279	-0.0082	1.151012	0	13.23	10587.4	6351.8	0	10583.9	6388.11	34.89214
125.8	10585.65	6352.279	-0.0082	0.782688	0	13.23	10587.4	6351.8	0	10583.9	6388.37	34.89214
125.8167	10585.55	6352.279	-0.0082	0.690607	0	12.97	10587.4	6351.8	0	10583.8	6388.63	34.89214
125.8333	10585.46	6352.278	-0.0082	0.690607	0	12.97	10587.4	6351.8	0	10583.8	6388.89	34.89214
125.85	10585.36	6352.278	-0.0082	0.828729	0	12.84	10587.4	6351.8	0	10583.8	6389.15	34.89214

125.8667	10585.26	6352.278	-0.0082	0.552486	0	12.71	10587.4	6351.8	0	10583.8	6389.41	34.88599
125.8833	10585.17	6352.277	-0.0082	0.782688	0	12.58	10587.4	6351.8	0	10583.8	6389.67	34.88599
125.9	10585.08	6352.277	-0.0082	0.828729	0	12.45	10587.4	6351.8	0	10583.8	6389.92	34.89214
125.9167	10584.99	6352.277	-0.0082	0.92081	0	12.45	10587.4	6351.8	0	10583.8	6390.19	34.95143
125.9333	10584.89	6352.276	-0.0082	0.644567	0	12.18	10587.4	6351.8	0	10583.8	6390.44	34.88033
125.95	10584.8	6352.276	-0.0082	0.782688	0	12.18	10587.4	6351.8	0	10583.8	6390.7	34.88599
125.9667	10584.71	6352.276	-0.0082	0.782688	0	12.05	10587.4	6351.8	0	10583.7	6390.96	34.88033
125.9833	10584.63	6352.275	-0.0082	0.782688	0	11.92	10587.4	6351.8	0	10583.7	6391.22	34.88033
126	10584.54	6352.275	-0.0082	0.92081	0	11.79	10587.4	6351.8	0	10583.7	6391.48	34.88599
126.0167	10584.45	6352.275	-0.0082	0.96685	0	11.79	10587.4	6351.8	0	10583.7	6391.74	34.87516
126.0333	10584.36	6352.275	-0.0082	0.598526	0	11.53	10587.4	6351.8	0	10583.7	6392	34.94578
126.05	10584.28	6352.274	-0.0082	0.828729	0	11.53	10587.4	6351.8	0	10583.7	6392.26	34.88033
126.0667	10584.19	6352.274	-0.0082	0.690607	0	11.4	10587.4	6351.8	0	10583.7	6392.52	34.87516
126.0833	10584.11	6352.274	-0.0082	0.874769	0	11.27	10587.4	6351.8	0	10583.7	6392.78	34.87516
126.1	10584.03	6352.274	-0.0082	0.782688	0	11.14	10587.4	6351.8	0	10583.7	6393.04	34.94578
126.1167	10583.94	6352.274	-0.0082	0.782688	0	11.01	10587.4	6351.8	0	10583.6	6393.3	34.87516
126.1333	10583.86	6352.274	-0.0082	0.782688	0	10.87	10587.4	6351.8	0	10583.6	6393.56	34.87048
126.15	10583.78	6352.273	-0.0082	0.736648	0	10.87	10587.4	6351.8	0	10583.6	6393.82	34.87516
126.1667	10583.7	6352.273	-0.0082	0.828729	0	10.74	10587.4	6351.8	0	10583.6	6394.08	34.94062
126.1833	10583.62	6352.273	-0.0082	0.736648	0	10.61	10587.4	6351.8	0	10583.6	6394.34	34.87048
126.2	10583.54	6352.273	-0.0082	0.736648	0	10.48	10587.4	6351.8	0	10583.6	6394.6	34.87048
126.2167	10583.47	6352.273	-0.0082	0.92081	0	10.48	10587.4	6351.8	0	10583.6	6394.86	34.93596
126.2333	10583.39	6352.273	-0.0082	0.92081	0	10.35	10587.4	6351.8	0	10583.6	6395.12	34.87048
126.25	10583.31	6352.273	-0.0082	0.736648	0	10.09	10587.4	6351.8	0	10583.6	6395.38	34.87048
126.2667	10583.24	6352.273	-0.0082	0.736648	0	10.22	10587.4	6351.8	0	10583.6	6395.64	34.93596
126.2833	10583.16	6352.273	-0.0082	1.012891	0	9.957	10587.4	6351.8	0	10583.6	6395.9	34.87048
126.3	10583.09	6352.273	-0.0082	0.782688	0	9.957	10587.4	6351.8	0	10583.6	6396.16	34.8663
126.3167	10583.02	6352.273	-0.0082	0.828729	0	9.826	10587.4	6351.8	0	10583.5	6396.42	34.93178
126.3333	10582.94	6352.273	-0.0082	0.736648	0	9.695	10587.4	6351.8	0	10583.5	6396.68	34.87048
126.35	10582.87	6352.273	-0.0082	1.104972	0	9.695	10587.4	6351.8	0	10583.5	6396.94	34.93178
126.3667	10582.8	6352.273	-0.0082	1.104972	0	9.433	10587.4	6351.8	0	10583.5	6397.2	34.8663
126.3833	10582.73	6352.273	-0.0082	0.92081	0	9.433	10587.4	6351.8	0	10583.5	6397.46	34.8663
126.4	10582.66	6352.273	-0.0082	0.828729	0	9.433	10587.4	6351.8	0	10583.5	6397.72	34.92809
126.4167	10582.59	6352.273	-0.0082	0.828729	0	9.171	10587.4	6351.8	0	10583.5	6397.98	34.8663
126.4333	10582.52	6352.273	-0.0082	0.828729	0	9.171	10587.4	6351.8	0	10583.5	6398.24	34.93178
126.45	10582.46	6352.273	-0.0082	0.828729	0	9.171	10587.4	6351.8	0	10583.5	6398.5	34.86261
126.4667	10582.39	6352.273	-0.0082	0.828729	0	8.909	10587.4	6351.8	0	10583.5	6398.76	34.92809
126.4833	10582.32	6352.273	-0.0082	0.506445	0	8.909	10587.4	6351.8	0	10583.5	6399.02	34.86261
126.5	10582.26	6352.274	-0.0082	0.828729	0	8.778	10587.4	6351.8	0	10583.5	6399.28	34.86261
126.5167	10582.19	6352.274	-0.0082	0.598526	0	8.778	10587.4	6351.8	0	10583.5	6399.54	34.92809
126.5333	10582.13	6352.274	-0.0082	0.782688	0	8.516	10587.4	6351.8	0	10583.4	6399.8	34.86261
126.55	10582.06	6352.274	-0.0082	0.782688	0	8.647	10587.4	6351.8	0	10583.4	6400.06	34.92809
126.5667	10582	6352.274	-0.0082	0.736648	0	8.385	10587.4	6351.8	0	10583.4	6400.32	34.86261
126.5833	10581.94	6352.275	-0.0082	0.690607	0	8.385	10587.4	6351.8	0	10583.4	6400.58	34.9249
126.6	10581.88	6352.275	-0.0082	0.782688	0	8.254	10587.4	6351.8	0	10583.4	6400.84	34.86261
126.6167	10581.82	6352.275	-0.0082	0.644567	0	8.254	10587.4	6351.8	0	10583.4	6401.1	34.9249
126.6333	10581.75	6352.275	-0.0082	0.828729	0	8.123	10587.4	6351.8	0	10583.4	6401.36	34.86261
126.65	10581.7	6352.276	-0.0082	0.828729	0	7.992	10587.4	6351.8	0	10583.4	6401.62	34.9249
126.6667	10581.64	6352.276	-0.0082	0.736648	0	7.992	10587.4	6351.8	0	10583.4	6401.88	34.85941
126.6833	10581.58	6352.276	-0.0082	0.782688	0	7.861	10587.4	6351.8	0	10583.4	6402.14	34.9249
126.7	10581.52	6352.277	-0.0082	0.736648	0	7.861	10587.4	6351.8	0	10583.4	6402.4	34.85941
126.7167	10581.46	6352.277	-0.0082	0.874769	0	7.73	10587.4	6351.8	0	10583.4	6402.66	34.9249

126.7333	10581.4	6352.277	-0.0082	0.828729	0	7.599	10587.4	6351.8	0	10583.4	6402.92	34.8567
126.75	10581.35	6352.278	-0.0082	0.782688	0	7.599	10587.4	6351.8	0	10583.4	6403.18	34.9249
126.7667	10581.29	6352.278	-0.0082	0.782688	0	7.468	10587.4	6351.8	0	10583.4	6403.44	34.85941
126.7833	10581.24	6352.279	-0.0082	0.736648	0	7.468	10587.4	6351.8	0	10583.4	6403.7	34.9222
126.8	10581.18	6352.279	-0.0082	0.736648	0	7.337	10587.4	6351.8	0	10583.4	6403.96	34.85941
126.8167	10581.13	6352.279	-0.0082	0.828729	0	7.206	10587.4	6351.8	0	10583.3	6404.22	34.9222
126.8333	10581.07	6352.28	-0.0082	0.782688	0	7.206	10587.4	6351.8	0	10583.3	6404.48	34.8567
126.85	10581.02	6352.28	-0.0082	0.782688	0	7.206	10587.4	6351.8	0	10583.3	6404.74	34.9222
126.8667	10580.97	6352.281	-0.0082	0.782688	0	7.075	10587.4	6351.8	0	10583.3	6405	34.9222
126.8833	10580.92	6352.281	-0.0082	0.874769	0	6.944	10587.4	6351.8	0	10583.3	6405.26	34.8567
126.9	10580.86	6352.282	-0.0082	0.736648	0	6.944	10587.4	6351.8	0	10583.3	6405.52	34.9222
126.9167	10580.81	6352.282	-0.0082	0.828729	0	6.813	10587.4	6351.8	0	10583.3	6405.78	34.8567
126.9333	10580.76	6352.283	-0.0082	0.874769	0	6.813	10587.4	6351.8	0	10583.3	6406.04	34.9222
126.95	10580.71	6352.284	-0.0082	0.828729	0	6.814	10587.4	6351.8	0	10583.3	6406.3	34.8567
126.9667	10580.66	6352.284	-0.0082	0.828729	0	6.551	10587.4	6351.8	0	10583.3	6406.56	34.9222
126.9833	10580.61	6352.285	-0.0082	0.874769	0	6.682	10587.4	6351.8	0	10583.3	6406.82	34.85448
127	10580.57	6352.285	-0.0082	0.92081	0	6.42	10587.4	6351.8	0	10583.3	6407.08	34.9222
127.0167	10580.52	6352.286	-0.0082	0.736648	0	6.551	10587.4	6351.8	0	10583.3	6407.34	34.91998
127.0333	10580.47	6352.286	-0.0082	0.782688	0	6.42	10587.4	6351.8	0	10583.3	6407.6	34.8567
127.05	10580.42	6352.287	-0.0082	0.828729	0	6.29	10587.4	6351.8	0	10583.3	6407.86	34.91998
127.0667	10580.38	6352.288	-0.0082	0.782688	0	6.289	10587.4	6351.8	0	10583.3	6408.12	34.85448
127.0833	10580.33	6352.288	-0.0082	0.782688	0	6.158	10587.4	6351.8	0	10583.3	6408.38	34.91998
127.1	10580.28	6352.289	-0.0082	0.736648	0	6.159	10587.4	6351.8	0	10583.3	6408.64	34.8567
127.1167	10580.24	6352.29	-0.0082	0.828729	0	6.027	10587.4	6351.8	0	10583.3	6408.9	34.91998
127.1333	10580.19	6352.29	-0.0082	0.506445	0	6.027	10587.4	6351.8	0	10583.3	6409.16	34.91998
127.15	10580.15	6352.291	-0.0082	0.782688	0	6.028	10587.4	6351.8	0	10583.3	6409.42	34.85448
127.1667	10580.1	6352.292	-0.0082	0.828729	0	5.896	10587.4	6351.8	0	10583.3	6409.68	34.91826
127.1833	10580.06	6352.292	-0.0082	0.782688	0	5.766	10587.4	6351.8	0	10583.3	6409.94	34.85448
127.2	10580.02	6352.293	-0.0082	0.828729	0	5.765	10587.4	6351.8	0	10583.2	6410.2	34.91998
127.2167	10579.98	6352.294	-0.0082	0.828729	0	5.766	10587.4	6351.8	0	10583.2	6410.46	34.85448
127.2333	10579.93	6352.294	-0.0082	0.828729	0	5.634	10587.4	6351.8	0	10583.2	6410.72	34.91998
127.25	10579.89	6352.295	-0.0082	0.92081	0	5.635	10587.4	6351.8	0	10583.2	6410.98	34.91826
127.2667	10579.85	6352.296	-0.0082	0.782688	0	5.503	10587.4	6351.8	0	10583.2	6411.24	34.85448
127.2833	10579.81	6352.297	-0.0082	0.782688	0	5.373	10587.4	6351.8	0	10583.2	6411.5	34.91826
127.3	10579.77	6352.297	-0.0082	0.874769	0	5.503	10587.4	6351.8	0	10583.2	6411.76	34.85448
127.3167	10579.73	6352.298	-0.0082	0.96685	0	5.373	10587.4	6351.8	0	10583.2	6412.02	34.91826
127.3333	10579.69	6352.299	-0.0082	0.92081	0	5.242	10587.4	6351.8	0	10583.2	6412.28	34.91998
127.35	10579.65	6352.3	-0.0082	0.736648	0	5.241	10587.4	6351.8	0	10583.2	6412.54	34.85276
127.3667	10579.61	6352.301	-0.0082	0.828729	0	5.111	10587.4	6351.8	0	10583.2	6412.8	34.91826
127.3833	10579.58	6352.301	-0.0082	0.874769	0	5.11	10587.4	6351.8	0	10583.2	6413.06	34.85276
127.4	10579.54	6352.302	-0.0082	0.874769	0	5.111	10587.4	6351.8	0	10583.2	6413.32	34.91998
127.4167	10579.5	6352.303	-0.0082	0.874769	0	4.979	10587.4	6351.8	0	10583.2	6413.58	34.91826
127.4333	10579.46	6352.304	-0.0082	0.828729	0	4.98	10587.4	6351.8	0	10583.2	6413.84	34.85276
127.45	10579.43	6352.305	-0.0082	0.506445	0	4.849	10587.4	6351.8	0	10583.2	6414.1	34.91826
127.4667	10579.39	6352.305	-0.0082	0.782688	0	4.848	10587.4	6351.8	0	10583.2	6414.36	34.85276
127.4833	10579.36	6352.306	-0.0082	0.874769	0	4.718	10587.4	6351.8	0	10583.2	6414.62	34.91826
127.5	10579.32	6352.307	-0.0082	0.736648	0	4.717	10587.4	6351.8	0	10583.2	6414.88	34.91826
127.5167	10579.29	6352.308	-0.0082	0.828729	0	4.718	10587.4	6351.8	0	10583.2	6415.14	34.85153
127.5333	10579.25	6352.309	-0.0082	0.782688	0	4.587	10587.4	6351.8	0	10583.2	6415.4	34.91826
127.55	10579.22	6352.31	-0.0082	0.828729	0	4.459	10587.4	6351.8	0	10583.2	6415.66	34.85276
127.5667	10579.18	6352.311	-0.0082	0.828729	0	4.457	10587.4	6351.8	0	10583.2	6415.92	34.91826
127.5833	10579.15	6352.313	-0.0082	0.690607	0	4.328	10587.4	6351.8	0	10583.2	6416.18	34.91703

127.6	10579.12	6352.314	-0.0082	0.644567	0	4.328	10587.4	6351.8	0	10583.2	6416.44	34.85276
127.6167	10579.09	6352.315	-0.0082	0.874769	0	4.066	10587.4	6351.8	0	10583.2	6416.7	34.91826
127.6333	10579.06	6352.317	-0.0082	0.598526	0	4.197	10587.4	6351.8	0	10583.2	6416.96	34.91703
0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C: DERIVED DATA

Table C1: Horizontal visibility blockage derived data
0=NO, 1=YES

Horizontal visibility											
Name	Gender	Age Group	Accident	Decelaration rate (ft/sec2)	Response time (sec)	Velocity (mph)	Gap(ft)	Gap(sec)	Impact Velocity (mph)	Angular velocity (degree/sec)	Ratio (Response time/ Gap)
PC											
Rahul	M	0	NO	17.487	1.100	35.120	81.426	1.580		0.109	0.696
Dan	M	1	yes	21.858	1.750	34.330	51.354	1.020	12.970	0.015	1.716
Alaa	M	0	NO	14.230	2.867	28.830	171.372	4.052		-0.008	0.708
George	M	0	NO	20.319	1.316	33.018	107.905	2.228		-0.182	0.591
guide	M	0	NO	7.966	3.470	34.982	241.716	4.710		0.032	0.737
JasonV	M	0	NO	22.342	0.950	33.278	85.934	1.760		0.020	0.540
Jon	M	0	NO	24.073	2.000	33.411	80.891	1.650		0.441	1.212
Mike	M	0	NO	20.303	1.520	32.100	71.758	1.524		0.338	0.997
Perik	M	0	NO	12.866	1.830	30.790	169.729	3.758		-0.097	0.487
Recha	M	0	NO	15.849	0.933	33.800	77.452	1.562		0.109	0.597
Sharma	M	0	NO	10.342	3.164	30.520	147.873	3.303		0.086	0.958
Zack	M	0	NO	18.132	0.834	32.620	74.280	1.552		-0.002	0.537
Jennifer	F	1	yes	22.797	2.033	33.280	53.227	1.090	14.830	1.404	1.865
Kizzy	F	0	NO	18.411	1.283	31.180	111.172	2.430		0.083	0.528
Sarah	F	0	NO	20.704	2.880	33.676	61.633	1.248		1.761	2.309
Shannon	F	0	NO	25.805	1.700	35.110	61.709	1.198		-1.318	1.419
Zena	F	0	NO	12.293	-0.017	32.360	110.159	2.321		-0.038	-0.007
Cindy	F	0	NO	12.352	0.533	34.850	141.759	2.773		0.029	0.192
Pauline	F	0	NO	22.152	2.600	33.280	192.468	3.942		0.032	0.660
Dr. F	F	0	NO	15.066	5.330	24.330	198.692	5.567		0.030	0.957
LTV											
Benjamin	M	1	yes	21.844	1.950	34.330	47.533	0.944	20.180	0.533	0.484
Chad	M	0	NO	24.616	1.950	34.200	76.470	1.524		0.246	0.782
Chip	M	0	NO	18.279	1.633	32.101	86.813	1.843		-0.089	1.129
Joe	M	0	NO	22.592	0.599	36.031	56.436	1.068		0.048	1.782
Jose	M	1	yes	17.751	1.780	35.240	44.285	0.857	22.140	0.805	0.481
Juan	M	1	yes	15.492	0.930	34.850	61.900	1.211	21.140	0.006	1.302
Mike	M	0	NO	26.553	2.000	35.110	64.460	1.252		-0.322	0.626
Peter	M	0	NO	22.430	2.050	33.017	96.366	1.990		0.246	0.971
Piyush	M	1	yes	21.183	1.283	35.381	78.865	1.519	21.350	0.046	1.184
Tobin	M	0	NO	25.423	1.716	32.620	99.117	2.071		-0.032	1.207
Vito	M	0	NO	15.609	0.970	33.016	88.513	1.827		-0.058	1.884
Abir	F	1	yes	27.492	1.970	34.850	38.898	0.761	20.180	0.488	0.386
Andrea	F	1	yes	22.210	2.017	34.980	47.457	0.925	14.500	0.069	0.459
Crystal	F	1	yes	21.932	1.050	34.850	64.766	1.267	13.800	-0.084	1.206
Ethling	F	1	yes	26.421	1.883	35.244	38.630	0.747	20.180	-0.406	0.397
Jennifer	F	0	NO	25.159	2.066	33.410	124.724	2.545		0.260	1.232
Johanna	F	0	NO	20.758	2.450	31.050	96.633	2.121		0.155	0.866
Carol	F	0	NO	21.257	2.333	38.259	164.586	2.932		0.087	1.257
Nicole	F	1	yes	23.413	1.900	33.807	62.550	1.261	7.110	-0.415	0.664
Kevin	M	0	NO	24.176	1.980	33.680	72.064	1.459		0.125	0.737

Table C2: Vertical visibility blockage derived data (0=NO, 1=YES)

NAME	GENDER	RED L-R	STOP IN MIDDLE	DECELERATION RATE (FT/SEC/SEC)	RESPONSE RESPONSE TIME (SEC)	VELOCITY (MPH)	GAP (FT)
Vertical Car							
Abir	F	0	0	9.76	1.81	36.03	279.7709
Andrea	F	1	0	10.41	8.58	34.06	90.81808
Carol-	F	0	0	4.53	6.43	27.51	354.9714
Crystal	F	0	0	7.43	-0.017	36.56	85.79815
Jennifer	F	0	0	6.84	-0.017	29.61	70.44307
Johanna	F	0	0	8.28	1.68	39.3	121.5939
Nicole	F	0	0	6.03	1.27	31.84	84.91228
Ethling	F	0	0	7.74	0.4	30.01	70.57431
Ben	M	0	0	14.69	1.88	38.39	78.71119
Hoze	M	1	0	6.44	1.734	36.68	54.72708
Juan	M	0	0	12.27	3.2	32.76	132.8149
Kevin	M	0	0	5.56	1.25	39.84	180.0613
Mike	M	0	0	5.75	1.25	35.11	82.09062
Peter	M	0	0	10.5	1.283	34.85	92.26172
Piyush	M	0	0	7.85	1.62	36.69	129.5011
Satoshi	M	0	0	11.01	1.42	38.52	131.5681
Toby	M	0	0	7.941	0.65	36.82	254.9337
Vito	M	0	0	9.64	1.27	35.51	155.7491
Chad	M	0	0	5.41	2.95	29.22	207.8514
Chip	M	0	0	3.54	3.3	31.97	65.2919
Joe	M	0	0	4.19	6.08	27.25	479.8134
Vertical Truck							
Cindy	F	1	0	13.46	10.03	36.55	178.2567
Dr. F	F	0	0	3.54	6.85	27.12	599.6356
Jennifer	F	0	0	4.87	-0.02	36.43	173.9258
Kizzy	F	1	0	4.23	-0.02	36.68	53.64435
Pauline	F	1	0	8.104	4.42	32.23	189.7074
Shannon	F	1	0	15.24	6.53	34.47	63.88107
Zena	F	1	0	26.9	5.72	36.69	66.04653
Sarah	F	0	0	2.68	2.01	29.74	367.2095
Dan	M	1	0	18.58	11.18	34.2	113.3914
Alaa	M	0	0	7.48	3.65	31.7	265.8922
George	M	1	0	5.06	1.75	37.86	69.68844
Guide	M	0	0	6.26	4.95	38.39	387.0268
Jon	M	1	0	5.04	2.63	39.96	191.5776
Mike	M	0	0	9.17	2.77	34.59	181.2096
Perik	M	0	0	9.91	4.63	39.18	177.2068
Rahul	M	0	0	20	4.83	34.98	176.9443
Rmair	M	1	1	27.75	4.42	37.21	67.49017
Sharma	M	0	0	8.37	1.97	36.43	130.6166
Zack	M	0	0	5.01	2.88	32.49	182.2596
Jasonv	M	1	1	9.23	4.83	32.1	104.4999

APPENDIX D: SURVEY QUESTIONS

SIMULATOR CAR SURVEY QUESTIONS

GROUP A

A- Scenario 1- Horizontal visibility blockage

1-) How do you rate the simulator car driving relatively to real cars driving. Range from 1 to 5

Brakes : 1 2 3 4 5

Acceleration: 1 2 3 4 5

Deceleration: 1 2 3 4 5

2-) Did you drive the simulator car similarly to how you drive your car on the road (attention, speed…)

Yes No Other ___________________________________

3-) Do you usually drive closely behind a passenger car in similar circumstances?

Yes No

4-) Did you see the car making a left turn before the leading car started braking?

Yes No

5-) Do you encounter similar visibility problems in real life?

Yes No

6-) Rate the scenario components (surrounding, audio, and visual)

1 2 3 4 5

B- Scenario 2- Vertical visibility blockage

1-) Did you see the traffic signal pole?

Yes **No**

2-) If you saw the traffic signal pole was it too late to stop?

Yes **No**

3-) Do you usually drive closely behind a truck or bus in similar circumstances?

Yes **No**

4-) Do you encounter this visibility problem in your daily life?

Yes **No**

GROUP B

C- **Scenario 1- Horizontal visibility blockage**

1-) How do you rate the simulator car driving relatively to real cars driving. Range from 1 to 5

Brakes : 1 2 3 4 5

Acceleration: 1 2 3 4 5

Deceleration: 1 2 3 4 5

2-) Did you drive the simulator car similarly to how you drive your car on the road (attention, speed…)

Yes No Other ___________________________________

3-) Do you usually drive closely behind a Van or SUV in similar circumstances?

Yes No

4-) Did you see the car making a left turn before the leading car started braking?

Yes No

5-) Do you encounter similar visibility problems in real life?

Yes No

6-) Rate the scenario components (surrounding, audio, and visual)

1 2 3 4 5

D- **Scenario 2- Vertical visibility blockage**

1-) Did you see the traffic signal pole?

Yes No

2-) If you saw the traffic signal pole was it too late to stop?

Yes **No**

3-) Do you usually drive <u>closely</u> behind a passenger car in similar circumstances?

Yes **No**

4-) Do you encounter this visibility problem in your daily life?

Yes **No**

GROUP C

1-) How do you rate the simulator car driving relatively to real cars driving. Range from 1 to 5

Brakes : 1 2 3 4 5

Acceleration: 1 2 3 4 5

Deceleration: 1 2 3 4 5

2-) Did you drive the simulator car similarly to how you drive your car on the road (attention, speed…)

Yes No Other ___________________________________

3-) Do you usually drive closely behind a truck or bus in similar circumstances?

Yes No

4-) Did you see the traffic signal pole in front of you?

Yes No

5-) Do you encounter similar visibility problems in real life?

Yes No

6-) Did you see the traffic signal pole on your right?

Yes No

7-) Do you think that the traffic signal pole on your right is helpful?

Yes No Other ______________________________

8-) Rate the scenario components (surrounding, audio, and visual)

1 2 3 4 5

APPENDIX E: PILOT STUDY MINITAB OUTPUT

PART I

1- Test and CI for Two Proportions

```
Sample  X   N  Sample p
1       5  10  0.500000
2       2  10  0.200000


Difference = p (1) - p (2)
Estimate for difference:  0.3
95% CI for difference:  (-0.0968625, 0.696862)
Test for difference = 0 (vs not = 0):  Z = 1.48  P-Value = 0.138


* NOTE * The normal approximation may be inaccurate for small samples.

Fisher's exact test: P-Value = 0.350
```

2- Test and CI for Two Proportions

```
Sample  X  N  Sample p
1       4  5  0.800000
2       2  5  0.400000


Difference = p (1) - p (2)
Estimate for difference:  0.4
95% CI for difference:  (-0.154362, 0.954362)
Test for difference = 0 (vs not = 0):  Z = 1.41  P-Value = 0.157

* NOTE * The normal approximation may be inaccurate for small samples.

Fisher's exact test: P-Value = 0.524
```

3-Test and CI for Two Proportions

```
Sample  X  N  Sample p
1       2  5  0.400000
2       0  5  0.000000
Difference = p (1) - p (2)
Estimate for difference:  0.4
95% CI for difference:  (-0.0294066, 0.829407)
Test for difference = 0 (vs not = 0):  Z = 1.83  P-Value = 0.068
* NOTE * The normal approximation may be inaccurate for small samples.
Fisher's exact test: P-Value = 0.444
```

4- Test and CI for Two Proportions

```
Sample  X  N  Sample p
1       4  5  0.800000
2       0  5  0.000000
Difference = p (1) - p (2)
Estimate for difference:  0.8
95% CI for difference:  (0.449391, 1)
Test for difference = 0 (vs not = 0):  Z = 4.47  P-Value = 0.000

* NOTE * The normal approximation may be inaccurate for small samples.

Fisher's exact test: P-Value = 0.048
```

PART II

Two-Sample T-Test and CI: SIM-PC, SIM-LTV

```
Two-sample T for SIM-PC vs SIM-LTV

          N  Mean  StDev  SE Mean
SIM-PC   10  53.3   31.4      9.9
SIM-LTV  10  49.7   20.9      6.6


Difference = mu (SIM-PC) - mu (SIM-LTV)
Estimate for difference:  3.61588
95% CI for difference:  (-21.77341, 29.00517)
T-Test of difference = 0 (vs not =): T-Value = 0.30  P-Value = 0.766  DF = 15
```

Two-Sample T-Test and CI: SIM-PC, SIM-LTV

```
Two-sample T for SIM-PC vs SIM-LTV

          N   Mean  StDev  SE Mean
SIM-PC   10  2.409  0.832     0.26
SIM-LTV  10  2.208  0.738     0.23


Difference = mu (SIM-PC) - mu (SIM-LTV)
Estimate for difference:  0.200646
95% CI for difference:  (-0.541393, 0.942685)
T-Test of difference = 0 (vs not =): T-Value = 0.57  P-Value = 0.576  DF = 17
```

Two-Sample T-Test and CI: SIM-PC, SIM-LTV

```
Two-sample T for SIM-PC vs SIM-LTV

          N  Mean  StDev  SE Mean
SIM-PC   10  78.1   15.3      4.8
SIM-LTV  10  72.5   25.0      7.9

Difference = mu (SIM-PC) - mu (SIM-LTV)
Estimate for difference:  5.53500
95% CI for difference:  (-14.33329, 25.40329)
T-Test of difference = 0 (vs not =): T-Value = 0.60  P-Value = 0.560  DF =
```

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