Horizontal Visibility Obstruction Due to LTV

Rami Harb, Ph.D. Student; Essam Radwan, Ph.D., P.E.; Xuedong Yan, Ph.D.

Center for Advanced Transportation System Simulation

University of Central Florida

Orlando, Florida 32816-2450 USA

Email: aeradwan@mail.ucf.edu

Phone: 407-823-0808

Fax: 407-823-4676

Abstract

In spring 2002, the Center for Advanced Traffic System Simulation (CATSS), at the University of Central Florida, acquired a sophisticated reconfigurable driving simulator. This driving simulator is capable of supporting research in driving simulation, driver training, traffic engineering and human factors. However, it is crucial to assess the validation of the driving simulator since the credibility of all the previous researches completed using the driving simulator relies on the validation of the latter.

This paper compares the results of an application of the driving simulator that consisted of studying the contribution of Light Truck Vehicles (LTV) to rear-end accidents with the results of Aty et al (2002) who pursued the same study using the crash database instead of the driving simulator as a source of data. In both studies, it was agreed that LTVs can obstruct horizontal visibility for the following car driver and that the sudden stop of LTVs may deprive the succeeding vehicle of sufficient reaction time, leading to high probability of rear-end collisions. A scenario illustrating a typical situation of horizontal view blockage was designed in the driving simulator and subjects from different ages and gender completed the experiment. Our study results showed that there is a statistically significant difference between the numbers of rear-ends collisions for following a passenger car and following an LTV with higher accidents probability for following an LTV. Those results comply with the results obtained by Aty in 2002. Therefore, the homogeneity between our results and Aty's results and the survey results suggest that the driving simulator can produce reasonable data that are very close to real life data.

Introduction

Horizontal visibility blockage has been a safety issue of great concern at unsignalized intersections leading to rear-end collisions. Moreover, according to Wang et al. (1999) rear-end collisions are the most common form of traffic crashes in the U.S. accounting for nearly 2 million crashes reported annually nationwide. 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 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 passenger cars (If the leading vehicle was wider and lower than the following vehicle, than the following vehicle could see the downstream traffic over the leading vehicle). 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 will be forced to slam on the brakes leaving the succeeding passenger car driver with almost no time to react appropriately and stop. This sequence of critical events can lead to a rear-end collision between the passenger car and the LTV.

To accredit the UCF driving simulator, we created a typical scenario leading to high probability of rear-end collision with LTVs in the driving simulator and our results were compared with the results of Aty et al. (2002) who completed the same study based on the national crash database.

LTV related literature review

According to the National Center for Statistics and Analysis (NCSA), in year 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. In the past two years, the National Transportation Safety Board investigated nine rear-end collisions in which 20 people died and 181 were injured. Common to all nine crashes was the rear following vehicle drivers' degraded perception of the traffic conditions ahead.
One of the main reasons of the increase in rear-end collisions relies on the abundance of 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 constitute 40% of all registered vehicles.

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. From the first 200 Seattle CIREN cases reviewed, 32 collisions with 41 occupant

cases were found to involve LTV versus PC. Acierno associated vehicle mismatch with death and serious injury in automotive crashes and recommended design improvement to both PC and LTV.

UCF driving simulator

The driving simulator acquired by the Center for Advanced Transportation Systems Simulation (CATSS) at the University of Central Florida is able to generate real life driving conditions. A passenger car (Saturn sedan), as shown in Figure 1, is mounted on a motion base providing the drivers with the same real car motions on the roads. 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.



Figure 1. Saturn Sedan mounted on a motion base with 5 channels of image generation

The driving simulator allows simulations with different types of vehicles and incorporates sophisticated vehicle dynamic models for different vehicle classes. The driving simulator also comprises of a visual database such as rural, suburban, and freeway roads in addition to 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, and/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 1. 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 in the experiment as also shown in Figure 1.

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 supervise the driver's reactions in the car. An emergency stop button is provided in the control room to immediately discontinue the driving if the driver undergoes motion sickness.

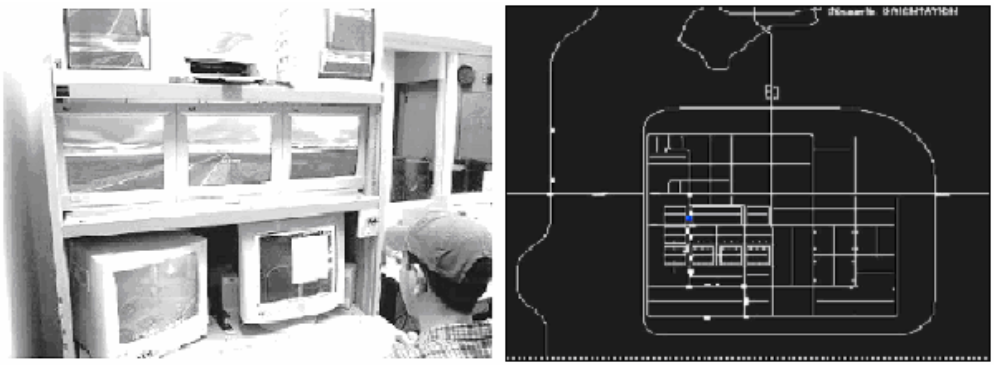


Figure 2. Control room and database road map

Experimental design

The horizontal visibility blockage scenario designed in the UCF driving simulator consisted of two sub-scenarios; sub-scenario one (or base scenario) where the driving simulator follows a passenger car and sub-scenario two (or the test sub-scenario) where the driving simulator follows an LTV. As shown in sub-scenario-1 in Figure 3 the leading passenger car does not obstruct the following passenger car driver's visibility. Therefore, at time T0, an aggressive driver from the opposite direction makes a sudden left turn. The leading and following vehicles' drivers can react at the same time T1, though decreasing the probability of rear-end collision.

In the second picture of Figure 3, which illustrates the test sub-scenario, at time T0, the car from the opposite direction makes a sudden left turn. The leading vehicle which is the LTV reacts to the event at time T1 and the following passenger car driver will react at time T2 when he perceives the LTV's brake lights. The following passenger car starts braking at T2 and can come to a complete stop at time T3 if (T3-T2) is long enough for it to stop. Otherwise, the following passenger car and the leading LTV will be involved in a rear-end collision.

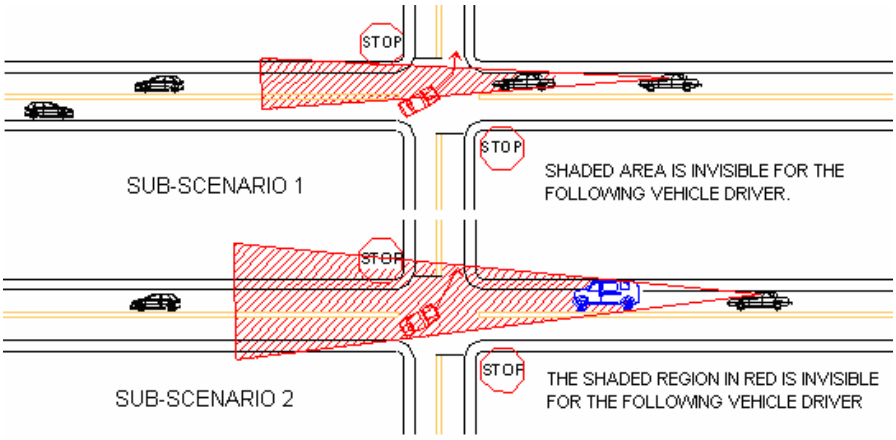


Figure 3. Horizontal visibility blockage sub-scenarios

Data collection method

Simulator Raw data

The driving simulator data collection software gathers a variety of data. When the scenario is designed, velocities, coordinates, acceleration and decelerations values are assigned ahead for the ambient traffic in the experiment. The data collection software collects the ambient traffic data and the following simulator car data with time interval 1/60 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.

Data Collection method

Before starting the formal experiment, a pilot study was conducted for the horizontal view blockage scenario consisting of two sub-scenarios. 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.

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 the 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) and the five remaining individuals started with SIM-PC then SIM-LTV. The purpose of this approach was to ensure that both sub-scenarios are treated equally.

The results of the pilot study confirmed that the same subject can not drive both sub-scenarios. In fact, when a driver drives the first sub-scenario, he can predict what is going to happen in the second sub-scenario since both sub-scenarios are exactly the same except for leading vehicle, which is a passenger car in the first sub-scenario and an LTV for the second sub-scenario.

Therefore, two groups A and B of subjects drove the driving simulator, where subjects from group A drove sub-scenario 1 and subjects from group B drove sub-scenario 2. Before starting the formal experiment, subjects were trained on the driving simulator for 5 minutes to familiarize them with the driving simulator. After the training, the subjects completed the experiment without knowing its content and purpose. At the end of the driving task, the subjects were asked to take a survey concerning their feedback to the experiment.

Sample size

The pilot study showed no significant difference between the numbers of potential rear-end collisions between SIM-LTV and SIM-PC sub-scenarios at 95% confidence interval. The obtained P-value (0.138) 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.

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.

p_1 = 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). And p_1 is defined in the equation below:

p_1=4/5=0 and q_1 = 1-p_1=1-0.8=0.2

p_2 = 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 p_2 is defined in the equation below:

p_2=2/5=0.4 and q_2 = 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.

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

The total required number of subjects recruited to complete the experiment is 25. To decrease the error margin, 40 subjects were recruited to complete the experiment. The age and gender distribution of the subjects followed the national crash database age and gender distribution where 60% of the driver were male and 40% female and where 60% of the drivers were over 25 years old and 40% of the subjects were between the ages of 18 and 25. Therefore group A consisted of 20 subjects and group B consisted of 20 subjects.

Data analysis and results

From the collected data, 2 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 were involved in a rear-end collision with the LTV. Therefore, the probability of rear-end collision with PC is 10% and the probability of rear-end collision with LTV is 40%. To determine whether there is a significant statistical difference between the two ratios a chi-square test was completed. The resulting P-value (0.013) 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.

Looking at the gaps between the simulator car and the leading vehicle in Figure 4, one can see that the gaps for following an LTV are smaller than the gaps for following a PC. A 2 sample t-test was performed to compare the means of gaps for following an LTV and PC and the resulting p-value (0.01) is less than 0.05. The mean gap for following an LTV is 75.6 ft and the gap mean for following a PC is 114.6ft. Therefore, there is a statistically significant difference between the means of the gaps with the gap for following an LTV smaller than the gap for following a PC. One can notice that the subjects with the smaller gaps were involved in a rear-end collision. Therefore, one can relate the gap to the probability of rear-end collisions In fact, the smaller gaps for following an LTV can be explained by the fact that subjects following an LTV were frustrated because the visibility of the traffic beyond the LTV was blocked. Therefore they stayed close to the leading vehicle waiting for an opportunity to pass it. Although following the LTV close would impede the visibility for the passenger car driver, the passenger car driver would not expect a sudden left turn from the opposing traffic but he was more looking for a more comfortable driving where he could see the traffic ahead clearly.

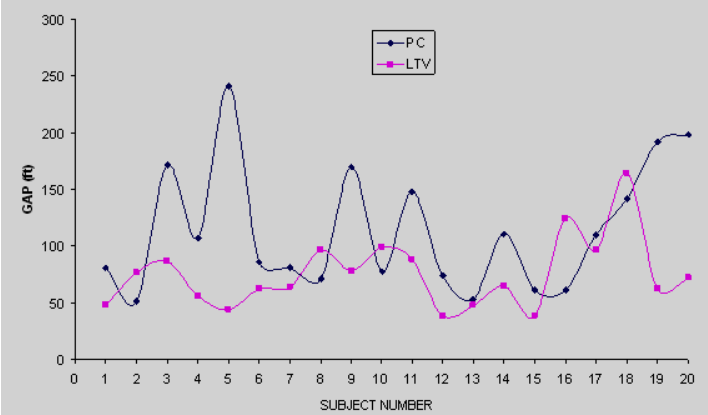


Figure 4. Gap for following a PC and following an LTV

As mentioned before, the subjects were asked to take a survey at the end of the experiment. One of the questions was if they saw the car from the opposite direction making a left turn. As shown in Figure 5 below, 50 % of the subjects driving behind a LTV said that they did not see the car making a left turn. The 40% of the subjects involved in a rear-end collision suffered from visibility blockage of the opposite left turning vehicle and the 10% remaining of the subjects who suffered visibility blockage escaped the accident. Since all the subjects that were involved in rear-end collisions reported that they suffered from visibility blockage one can indicate that rear-end collisions with LTV can be correlated with visibility obstruction.

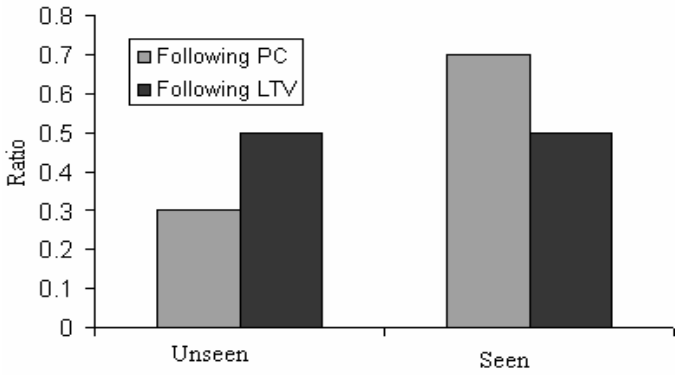


Figure 5. Seen or unseen car making a left turn

Conclusions

One of the paper's objectives was to study whether driving behind an LTV increases the probability of rear-end collisions. 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 which complies with Aty et al. Therefore, one can conclude that the UCF driving simulator produces reasonable data close to real life data.

References

Abdel-Aty, M., Abdelwahab, (2002) H.T. Configuration Analysis of Two-Vehicle Rear-End Crashes. Transportaion Research Board 82nd Annual Meeting, Washington D.C., US.

Acierno, S., Kaufman, Rivara, F.P., Grossman, D.C., Mock, C. 2004. Vehicle Mismatch: Injury Patterns and Severity. Accident Analysis and Prevention 36 (2004) 761-772.

National Center for Statistics and Analysis (NCSA), 2004, http://www-nrd.nhtsa.dot.gov