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DEVELOPMENT OF A SIMULATION TEST BED FOR CONNECTED VEHICLES USING THE LSU DRIVING SIMULATOR

Final Report

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EXECUTIVE SUMMARY

Traffic accidents in the U.S. have declined over the last two decades but continue to cost the country billions of U.S. dollars each year. Intersection collisions alone account for about 50% of the total number of annual accidents. A study of the characteristics of these accidents showed that 75% of intersection accidents resulted from driver error including driver inattention, faulty perception, and vision impaired/obstruction. There has been significant effort to overcome this problem over the past few years and it is viewed that connected vehicle technology may offer a very promising means to reduce, and maybe totally overcome, the driver error factor in intersection collisions. Part of this can be achieved through providing a properly designed system of collision warning messages to drivers at the right time that will allow drivers a suitable reaction time to avoid any potential collision. However, this is not always the case especially with the complex driving behavior that differs within any driver population based on factors such as, mood, age, and gender among others. These factors affect the way people drive in terms of the headway, speed, and perceived risk that is translated into the minimum time to collision value. Driver aggressiveness is the main attribute that captures the different driving styles of people, therefore two levels of aggressiveness were tested for this study.

From this perspective, a preliminary driving simulator test bed was developed in the driving simulator laboratory at Louisiana State University (LSU) so as to allow a lead vehicle to communicate warning messages to the simulator vehicle (connected vehicles technology) within the virtual environment. The main focus in this study was on designing a message alert system, based on time-to-collision between two vehicles, in the driving simulator environment. A pilot study was then undertaken with a group of aggressive and non-aggressive drivers to assess which group could most benefit from this technology when approaching intersection stop lines.

The test bed was designed in two stages: simulation network design and visual alerts design. The simulation network was designed as an undivided urban four lane roadway. It had a solid double yellow line down the center, solid white lines on the outside edges, dashed white lines separating the two lanes that go in each direction, and on a flat grade with a posted speed limit of 35 mph. A fine weather condition was selected to avoid any external. The alerts were designed as visual text messages that warned the driver of imminent potential crash with the lead vehicle. It was decided to omit auditory warnings because drivers were allowed to become familiar with the scenario surroundings before the actual test. The first of two visual warning messages was projected onto the driver's screen in a yellow font as "SLOW DOWN" when the driver's minimum time-to-collision (TTC) was down to 3 seconds. To determine which location in the simulator that the alert messages will be displayed to the drivers, a separate survey was undertaken with the view of identifying the preferred location empirically. A simple questionnaire was designed on "SurveyMonkey" website and the LSU Civil Engineering pool of graduate and undergraduate students were asked to choose their preferred location.

Thirty participants aged between 18 and 58 years of age (mean = 27.3, standard deviation = 8.17), and consisting of five females and twenty-five males were recruited from the Louisiana State University's community of students and staff. They were all of good general health, and were active drivers with a valid driver's license. Based on the participants' responses to the Larson

Driver's Stress Profile (LDSP) questionnaire, they were classified into 20 non-aggressive drivers and 10 aggressive drivers. Each participant was then required to perform three simulator drives: (a) test drive to get familiar with the network and the simulator vehicle, (b) one drive with the alert messages, and (c) a third drive without the alert messages. The rank of the latter two drives was randomly determined in order to nullify any learning effect. Vehicle trajectory data was collected for each drive and the time-to-collision (TTC) was calculated. Comparative t-test was then performed on the calculated TTC values for each drivers' group.

For non-aggressive drivers, the result [$t(19) = -0.32, p = 0.7561$] suggests that the null hypothesis cannot be rejected at a 5% level of significance. On the other hand, for aggressive drivers, the result [$t(9) = 2.58, p = 0.0297$] suggests that the null hypothesis can be rejected at the 5% level of significance, leading to the conclusion that the display of alert messages caused a significant difference in the driving behavior of aggressive drivers. The findings not only lend credence to the safety benefits of the connected vehicles technology, but also means that a driving simulator test bed can be harnessed to achieve similar goals as physical test beds. The successful development of the preliminary driving simulator test bed means future sensitivity tests can be undertaken to ascertain the optimal moment to prompt the activation of the alert messages. The addition of audio prompts to the current visual alert system can also be explored and a larger sample size can be utilized to analyze demographic effects of such technology. It is acknowledged that the present sample size is a limitation of the study. In addition, other driving characteristics such as speed, acceleration and time headways could be analyzed before and after the alert message in order to investigate potential adaptation effects in driving behavior. Furthermore, the preliminary test bed can be enhanced to allow more vehicles to communicate within the generated network of the driving simulator environment, and further benefits of the V2V technology explored.

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1.0 INTRODUCTION

Recently, the development of a fully connected transportation network has received special attention from researchers, federal and state government agencies, and public and private stakeholders. The concept of connected vehicles relies on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication technologies, which requires a robust platform to allow for not only creativity and interoperability, but also the ability to interact with the complex human behavior. Connected vehicles research relies on the usage of test beds to address the potential problems associated with the development and deployment of V2V and V2I technologies. Test beds for connected vehicles research can also be used for testing real time data capture and management systems, as well as testing the integration and interoperability of the connected vehicles, mobile devices, and highway infrastructure. Along with the physical platforms for test beds, driving simulator test beds for the connected vehicles environment can also be harnessed to achieve similar goals. More specifically, driving simulators are a high fidelity human-in-the-loop simulation platform that has a great potential to serve as a connected vehicles test bed.

The ability of driving simulation technology to interact with the complex human behavior is of great interest. However, to fully investigate the benefits of connected vehicles using this technology, a connected vehicle environment is to be defined and coded in the simulator. The use of a driving simulator test bed for connected vehicles allows for a controlled environment to test real-time data capture and the integration and operability of connected vehicles. With the driving simulator, the development of a simulation test bed for connected vehicles is now possible.

Traffic accidents in the U.S. have declined over the last two decades but continue to cost the country billions of U.S. dollars each year. Intersection collisions alone account for about 50% of the total number of annual accidents (Blincoe 2002). A study of the characteristics of these accidents showed that 75% of intersection accidents resulted from driver error including driver inattention, faulty perception, and vision impaired/obstruction. There has been significant effort to overcome this problem, over the past few years and it is viewed that connected vehicle technology may offer a very promising means to reduce, and maybe totally overcome, the driver error factor in intersection collisions (Lloyd 1996). Part of this can be achieved through providing a properly designed system of collision warning messages to drivers at the right time that will allow drivers a suitable reaction time to overcome any potential collision. However, this is not always the case especially with the complex driving behavior that differs within any driver population based on factors such as, mood, age, and gender. These factors affect the way people drive in terms of the headway, speed, and perceived risk that is translated into the minimum time to collision value. Driver aggressiveness is the main attribute that captures the different driving styles of people, therefore two levels of aggressiveness were tested for this study.

From this perspective, a preliminary connected vehicle environment was developed in the driving simulator laboratory at Louisiana State University (LSU) as to allow a lead vehicle to communicate warning messages to the simulator vehicle within the virtual environment. A pilot study was then undertaken with a group of aggressive and non-aggressive drivers to assess which group could most benefit from this technology when approaching intersection stop lines. It was anticipated

that a successful driving simulator test bed may impact on the driving behavior of the aggressive drivers, and thereby reduce the number of potential collisions at intersections.

1.1 LITERATURE REVIEW

Over the past few years, there has been an increasing emphasis on using connected vehicle technology to improve safety and efficiency of roadways. Simulation and physical test beds have been acknowledged as the means to test the benefits of such technology. Simulation test beds are of two main types: computer simulation and human-in-the-loop simulation test beds. The former incorporates the use of simulation software such as CORSIM, PARAMICS, VISSIM, SUMO, and Aimsum. In addition, network simulators are used to simulate Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications; examples include network simulator-1, ns-2, ns-3, and OMNeT. The latter, on the other hand, incorporate using driving simulators so that realistic human factors can be studied in a safe and non-destructive environment. Physical test beds are even more realistic as they incorporate using cars equipped with the technology to be driven on roadways (e.g. Mcity). Since the driving simulator is used in this study, the main focus in the rest of the background is given to driving-simulator based connected vehicle test beds.

1.1.1 Human-in-the-Loop Simulation

The J.J Slob's DCT report (Slob, J.J., 2008), State-of-the-Art Driving Simulators, a Literature Survey provides an in depth review of the history of driving simulators. The report states that the origin of motion simulation dates back to the early 20th century, when the Antoinette flight school first developed a flight simulator. It wasn't until the early 1970s that simulators were produced to test automobiles. The first companies to attempt driving simulation were Volkswagen and the Swedish Road and Traffic Research Institute. These original designs were simple and only consisted of three degrees of freedom. Later designs produced in the 1980s by Mazda began to incorporate a fourth degree of freedom. The six degrees of freedom were not used in driving simulator test beds until 1985, when Daimler Benz created their first driving simulator. Since then, there have been several driving simulators developed with the six degrees of freedom including heave, surge, sway, yaw, roll, and pitch.

Driving simulators can vary in realism and cost based on the funds available and the needs of the research project. 3D gaming engines can be created as low cost driving simulators using programs such as STSIM Drive and OpenEnergySim to operate the simulation on a PC. These engines are cheap and convenient, but lack the realism of an advanced simulator that is necessary to perform most connected vehicle tests. Medium cost simulators include large curved screens and more realistic vibrations intended to replicate the feel of an actual vehicle. Existing medium cost simulators can be found at University of Buffalo, University of Porto, and other universities around the world. The preferred style of driving simulator test beds utilizes high cost functions including a full-sized vehicle, 360 degrees' field of view, with realistic driving controls. Examples of high cost simulators can be found at U.S. automotive manufacturers including Toyota, GM, Honda, Ford, and BMW. University of Iowa has also created a MiniSim version of these simulators that uses cheaper hardware (Hou et al, 2015). In the following sections, different driving simulator test beds will be presented to show the effectiveness of using driving simulators as test beds.

1.1.2 Connected Vehicle Test Beds

The University of Iowa's National Advanced Driving Simulator (NADS-1) was first introduced during the North American Driving Simulation Conference in 2003 after being used in a study titled Development of an Off-Road Agriculture Virtual Proving Ground (Schwarz et al, 2003). Their simulator was extremely advanced for the time. The simulator consists of a complete car, 360 degrees of scenery and 4 actuators, with 13 degrees of freedom. These 13 degrees of freedom allow for the largest motion envelope in the United States and the second largest in the world. With all of the advanced sensory stimuli, the NADS-1 is the highest fidelity real-time driving simulator. The current vehicle selection includes a passenger sedan, a mid-sized sports utility vehicle, a heavy truck single cab, and an agricultural tractor cab. These vehicles are surrounded by 16 high definition projectors, creating a 40-degree vertical view along with 360 degrees of vision. The steering wheel, pedals, and seat have the ability to send feedback and simulate warning systems, which is extremely useful in connected vehicle studies. The simulator is programmed to measure displacement, velocity, acceleration, the main 6 degrees of freedom for motion, vibration displacement, and noise. Then the University of Iowa's National Advanced Driving Simulator (NADS-2) is introduced. The NADS-2 simulator is similar to the NADS-1, but it utilizes a fixed base, making it useful for tests that don't require motion. The NADS Minisim is a smaller, portable, low cost version of the NADS-1 which uses a 42 inch display and a quarter-cab configuration. Along with an existing library of scenarios, researchers are able to create their own scenarios for the Minisim using the Interactive Scenario Authoring Tool. The main reason to use Minisim rather than NADS-1 is that it is easily setup, configured, and taken down (The National Advanced Driving Simulator).

In addition, The University at Buffalo has integrated their driving simulator with PARAMICS, which is a traffic simulator, and NS-2, which is a communications Network Simulator to create an effective connected vehicle test bed. The integrated traffic driving networking simulator (ITDNS) allows researchers to study driver's responses to advisory messages using connected vehicle technology. Most Universities use the traffic simulator that is pre-programmed into the driving simulator, but this background traffic is often non-intelligent and fails to accurately represent human based traffic decisions. As a result, University at Buffalo incorporated a driving simulator to complement the traffic simulation program and make the environment more real. The traffic simulator at University of Buffalo (UB) uses PARAMICS v.6.0 to simulate models of freeway and arterial networks. The driving simulator consists of six degrees of freedom, a 1999 Ford Contour, a steering wheel, three floor pedals, a standard gear shifter, an emergency stop switch, digital mirror screens, and frontward simulation screens. The third component of the connected vehicle test bed is the NS-2 networking simulator, which is used to modify internal components of the network (Zhao et al, 2014).

The Idaho National Laboratory (INL) has created an advanced heavy vehicle driving simulator, located at the Center for Advanced Energy Studies, which can be used as a potential test bed for connected vehicle applications. Initially the INL used a driving simulator; HVS#1, that consisted of a racing style seat, G-27 Logitech steering wheel, pedals, shifter, and three 37 inch television screens. In 2014 drastic improvements were made to the HVS#1, thus creating the HVS#2 model. The HVS#2 utilizes an actual size bus cab with the same features seen in INL's current motor coaches. The new simulator displays a 110 inch picture across the front windshield that simulates the actual viewpoint of a bus driver in real life conditions. INL also incorporates the NADS

software mentioned previously at University of Iowa. This allows them to display realistic environmental conditions and obstacles. Along with the windshield projection, there are two small side mirror projectors used to simulate the view behind the vehicle and one digital dash projector used to display communication messages to the driver. This is useful for performing connected vehicle studies including V2V communications, collision mitigation, drift from lane center, animal warning system, and weather hazard warnings. The INL is currently using their simulator to test fleet fuel consumption patterns, and hopes to use connected vehicle technology to optimize fuel use driving patterns (Gertman et al, 2015). Other HV simulators that have been installed include the TUTOR model in Spain by Lander Simulation and Training Solutions and the Mark II from Transim. For the most part the TUTOR truck simulator is used for professional driver training rather than research (Slob, J.J., 2008).

In 2005, two state of the art driving simulators were created, incorporating the six degrees of freedom. The Katech Advanced Automotive Simulator (KAAS) and the CarSim based simulator at the German Aerospace Center's Institute for Transportation Systems (DLR) are advanced simulators with potential use for connected vehicles studies (Slob, J.J., 2008). KAAS is currently the largest simulator in Korea, allowing for 360 degrees field of vision and weighing five and a half tons. The KAAS model uses real time communication, allowing several hardware in the loop systems to be used with the main driving simulator scenarios. The simulation model also includes an in vehicle network simulation system, wireless communication simulation system, high speed signal analysis devices, a driver perception analysis system, and a GPS signal simulation system (Yu et al, 2007). Unique features of the KAAS model include a 17 degrees of freedom vehicle model, a 3D real city and highway database, a stereo type eye tracker, and a dome structure that surrounds the vehicle allowing for lighting control and 360 degrees projection. The simulator in Germany incorporates the advanced simulation and motion technology of CarSim into a Simtec simulation vehicle. The German Aerospace Center has also developed a multidriver simulator laboratory that allows researchers to study the behaviors and interactions of multiple connected vehicles operated by actual human participants. This Modular and Scalable Application platform for ITS Components (MoSAIC) has several advantages and an alarming amount of research potential for connected vehicle studies. The main limitations researchers at DLR have found is the lack of effective methods to study multidrivers, along with the issue that drivers know they are being studied, so they tend to exhibit more cooperative driving behavior than normal (Oeltz et al, 2015).

Built in 1993 by the Engineering Research Council (EPSRC), the Leeds Advanced Driving Simulator (LADS) began as a medium cost driving simulator. It was constructed initially to perform rural studies, but was later improved into to handle urban environments and vehicle interaction (Blana, E., 1996). This LADS model was used as a starting point for one of the most advanced simulators in existence today, the University of Leeds Advanced Driving Simulator (UoLADS). The UoLADS has been fully functioning since 2007 and is a capable connected vehicles test bed. The simulator features include 8 degrees of freedom, realistic cues of cornering, braking and road roughness, a full scale Jaguar S-type vehicle cab, a 4m diameter projection dome, an eye tracker, and a 3-D passive stereo system. All of the software used by the simulator is created in house using C++ programming (N8 Research Partnership, 2016). Recently researchers at University of Leeds have primarily used the UoLADS to run tests on automated vehicles and drivers' responses to switching between automation and manual control.

The University of Beijing performed multiple connected vehicle studies using a driving simulator from the MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology. The results of these tests are reported in Xuedong Yan's published work "The influence of in-vehicle speech warning timing on drivers' collision avoidance performance at signalized intersections" and "Driving-Simulator-Based Test on the Effectiveness of Auditory Red-Light Running Vehicle Warning System Based on Time-To-Collision Sensor (Yan et al, 2014)." The simulator method was chosen rather than field testing as the connected vehicle test bed because it allowed for higher safety conditions and a lower cost. The simulator was programmed to use auditory messages to warn test drivers of oncoming collisions due to connected vehicles running red lights. The test bed is designed to display warnings at varying times and measure brake reaction time, alarm to break onset time, and deceleration rate. The simulator consists of a Ford Focus, similar to the one at Louisiana State University, environmental noise control, vibration simulation system, one degree of motion platform, and a 300 degree front view display (Yan et al 2015).

The Commercial Training and Prototyping (CTAP) Simulator at Virginia Tech is an advanced driving simulator that is currently being utilized as a connected vehicle test bed. They developed a research team within the Center for Advanced Automotive Research (CARR) with the goal of increasing driver's safety through crash warnings, vehicle avoidance, and mitigation using connected vehicle technology. They are currently using the test bed to study vehicle based basic safety message deployment to show the benefits of CV technology and expedite the process of commercializing CV technology. The CTAP simulator uses a VTTI-DAS data collection program that uses the same format installed in modern trucks. This allows for an easy comparison between field data and simulator data. Within the simulator is a 225 degree frontal view, 3 degrees of freedom, the ability to switch from automatic to synchronized manual or 9-, 10-, or 13- speed non synchronized manual transmission. The model is also programmed to use geo-specific driving environments, creating a realistic driving setting for a CV test bed. Buses, straight trucks, trailer models, emergency vehicles, and military vehicles can also be tested using the CTAP simulator (Virginia Tech, 2016).

1.1.3 Connected Vehicles Applications

Over the past five years, the development of the connected vehicle applications has been a national interest. For each application, the assessments of safety, mobility and environmental impacts are conducted. Those real-life experiments will be used to estimate the difficulties in future impacts. For now, the USDOT has sponsored several research studies for connected vehicle applications. Many published studies described all the research process including concepts of operation, system requirements, and other related source. In general, connected vehicle applications can be separated into seven aspects: V2I (vehicle-to-infrastructure), V2V (vehicle-to-vehicle), agency data, environment, road weather, mobility and smart roadside (US DOT, 2015).

As an example of V2I connectivity, Holmes et al. (2014) assessed three different presentations of connected vehicle signalized intersection applications: integrated (e.g., in the center console), fixed to the windshield (e.g., an off-the-shelf navigation device), and mobile (e.g., cell phone). Each display device will present two types of connected vehicle applications: safety-related and non-

safety related. Research experiments were conducted to evaluate the performance of the application's display locations.

Holmes et al. (2014) study results showed that the drivers using either the fixed or the integrated display device will have higher compliance rate to the red-light warning than the drivers using mobile device with a compliance rate of 67% to 92%. For the non-safety related applications, the tested drivers take significantly longer time to read the information on the devices. Also, drivers have extremely low preference rating in non-driving related information. In conclusion, Holmes et al. (2014) suggested connected vehicle applications with unsecured mobile device may cause safety and acceptance concerns.

Not just the device location matters, the time used to deliver the warning message is also a crucial factor in the connected vehicle applications' performance. Yan et al. (2015) used experimental analyses by providing different range of delivery times of warnings and found the most efficient time ranges. In the experimental scenarios, the red light violation warning (RLVW) application was used in the red-light-running events at intersections. At the end of the test, several measures were adopted to reflect how drivers perform after receiving the warning, which are brake reaction time, alarm-to-brake-onset time and deceleration. Based on the research results, Yan et al (14) concluded that the warning system could reduce the red-light-running crashes, and 4.0 s or 4.5 s delivery-time works the best in this study.

Also some non-signalized intersection applications, under the connected vehicle environment, were tested. The Stop Sign Gap Assist application is proposed to improve safety at sign intersections where only the minor road has posted stop signs. The infrastructure on the roadside will equipped with signage warning systems and broadcast the traffic information. So when drivers reach the intersection on a minor road, the SSGA application will provide a warning of unsafe gaps on the major road to help drivers safely maneuver through cross traffic (Maile et al., 2008).

To evaluate The Stop Sign Gap Assist application performance, ENTERPRISE Pooled Fund Study "Design and Evaluation Guidance for Intersection Conflict Warning Systems (ICWS)" was conducted (CH2MHILL, 2015). Based on the MnDOT RICWS safety report, State of Minnesota conducted a pilot study that installed an Intersection Conflict Warning Systems (ICWS) on a specific region and analyze the effects in traffic conflicts. A rural, 2-lane county road intersection was selected. A dynamic warning system was deployed on the major and minor directions. On the major road, the signs were placed 600 ft ahead of the intersection. The minor road sign was placed on the other corner away from the red STOP sign. Also, the radar detection was used in both approaches to warn the vehicles on the major road when detected vehicles in the intersection. After applying the ICWS application, traffic conflicts in this intersection decreased 54%. The conflicts were measured based on the occurrence of sudden braking, sudden acceleration or swerving.

Except Minnesota, Missouri and North Carolina also conducted research study on ICWS with 9 and 4 experimental sites, respectively (CH2MHILL, 2015). Study results of Missouri sites revealed a 28% reduction in all crashes. For North Carolina, the before-and-after study at the 2-lane major/2-lane minor road showed a 46% reduction in crashes and a closely 20% reduction in crashes at 4-lane major/2-lane minor road.

As an example of V2V communication, Crash Warning System (CWS) applications are being researched and developed for automobiles as well as motorcycles. Song et al. (2016) studied issues of Intersection Movement Assist (IMA), Forward Collision Warning (FCW), and Lane Change Warning (LDW) with prototypes incorporating visual, auditory, and haptic alerts.

When the drivers plan to change lane, LCW application will alert the drivers when there is a blind spot in the same direction traffic. This system is also applicable when other V2V equipped vehicle try to change a lane, and the driver of host vehicle is in the other car's blind spot. The IMA application will warn the drivers when it is unsafe to enter an intersection. One of the reasons could be the driver's view is blocked or high probability of collision. Forward Collision Warning is used to alert drivers to avoid rear-end collision. This application will respond to a direct threat ahead of the driver realize. While visual alerts indicated the need for further work to avoid being distracting, the combination of auditory and haptic displays (with wristbands) showed significant potential for adoption by motorcycle riders.

Concerning the environmental aspect for the connected vehicles application, the Eco-Signal Operations Transformative Concept is introduced in the connected vehicle technologies that are aiming to decrease fuel consumption and emission. The air pollutant emissions could come from the number of stops, unnecessary accelerations and decelerations and the inefficient traffic flow at signalized intersections. The Eco-system is achieved by collecting connected vehicle technologies' data from vehicles, which includes vehicle location, speed, and emissions data. Then the system determines the optimal operation of the traffic signal system (Schneeberger et al., 2013).

Yang et al. (2015) studied Eco-Cooperative Adaptive Cruise Control (Eco-CACC) systems and presented an algorithm to reduce fuel consumption in vehicles. The Eco-CACC application will collect speed, acceleration, and location information of other vehicles, then using connected vehicle technologies to integrate these data into a vehicle's adaptive cruise control system. As a result, the analyzed vehicle is not only capable of automated longitudinal control, but also able to reduce fuel consumption and emissions.

In Yang et al.' research (2015), the algorithm utilizes Signal Phasing and Timing (SPaT) data and provides drivers of the connected vehicles with optimal speeds. For single-lane intersections, fuel savings of up to 18% were realized, while for multi-lane intersections, savings were generated only when the Market Penetration Rates (MPR) were more than 30%.

Huff et al. (2015) researched the application of vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) technologies to connected transit vehicles. Applications including transit stop devices, anti-bunching communication, crash avoidance, and vehicle re-routing were studied. At bus stops serving multiple routes, connected devices at transit stops would enable buses to bypass the stop if no passengers requested pick up, increasing the transit system efficiency. Managed lanes, including High-Occupancy Vehicle (HOV) and High-Occupancy Toll (HOT) lanes could be configured based on real-time information, with numerous potential benefits ranging from improving movement of emergency vehicles to reducing air pollution "hotspots".

Since mobility is one of the most important aspects that will be achieved by the connected vehicle technology, Ahn et al. (2016) conducted a simulation study with the Multi-Modal Intelligent

Transportation Signal System (MMITSS). MMITSS applications are used to maximize the signal efficiency and are aimed for transit, freight, visually impaired pedestrians or emergency vehicles.

In this research study, two MMITSS applications, Intelligent Traffic Signal System (I-SIG) and Freight Signal Priority (FSP), are evaluated. Intelligent Traffic Signal System (I-SIG) will optimize the signal system by cooperating the signal priority and pedestrian movements. Freight Signal Priority (FSP) application will offer signal right-of-way for freight vehicles when near a freight facility or other arterial corridor (Ahn et al., 2016).

Ahn et al. (2016) found that the Freight Signal Priority (FSP) and the Intelligent Traffic Signal System (I-SIG) applications reduced vehicle delays and travel time by 20% and travel time variability by up to 56% for connected trucks. However, the system-wide delay increased due to reduced green time on side streets.

On the operations of the roadway system, weather condition will significant influence the safety, travel reliability, productivity and efficiency of the traffic flow. As a result, cooperation between the weather station information and vehicle real-time weather update will provide the optimum system performance. It is achieved by reporting the weather and traffic information to the drivers ahead of reaching the specific region, providing the best route in accordance to the weather condition and others. On the other hand, the data from connect vehicles can also be used to forecast and assess the impacts that weather has on roads. This application will dramatically change the existing management system to a weather-sensitive transportation system (Hill, 2013).

A case study was conducted in Indiana Department of Transportation (INDOT) by McCullough et al. (2007) to develop and evaluate a winter operations system in the statewide wireless network (SAFE-T) that has been mostly used by the state police. This network operates GPS, sensors to produce real-time information road and weather conditions. For example, the maintenance vehicle produces detailed information about chemical distribution on icing road and plow position. In addition, the system can transfer the data to a maintenance decision support system (MDSS), which can provide drivers the proper reactions to snow plow operator including recommended treatment plans and weather response plans. In the case study, several bugs and software issues were discovered and updated. Up to 2007, the application was expanded up to 10 snowplow vehicles. The evaluation of the benefits and the effects is still a continuing process.

As an application between the cooperation between roadside information (e.g., hours of service, location and supply of parking) with commercial drivers' information (e.g., loading/unloading scheduling, hours of service), higher safety of truck drivers could be achieved. Several research studies related to smart roadside applications are processing. One of the on-going research studies is a NCHRP project 20-102 led by Rofers et al. (2015). The objects of the research study are identifying the current policy related to freight and proposing the deployment of the applications.

In conclusion, the research studies in connected vehicle are in an on-going process. In the meantime, more than 30 connected vehicle applications concepts have been developed, which can be separated into seven main categories: V2I (vehicle to infrastructure), V2V (vehicle to vehicle), agency data, environment, road weather, mobility and smart roadside. In Holmes et al. research study, the research team suggested connected vehicle applications with unsecured mobile device may cause safety and acceptance concerns. Also, Yan et al. concluded that the warning system

could reduce the red-light-running crashes, and 4.0 s or 4.5 s delivery-time works the best in this study. On the other hand, the concept of Stop Sign Gap Application is adopted in an ENTERPRISE Pooled Fund Study. The study showed that SSGA could reduce the crash from 20%-54%, depend on the location. As an example of V2V communication, Song et al. concluded that while visual alerts indicated the need for further work to avoid being distracting, the combination of auditory and haptic displays (with wristbands) showed significant potential for adoption by motorcycle riders. In environmental aspect, Yang et al.' research studied Eco-Cooperative Adaptive Cruise Control (Eco-CACC) systems, and showed fuel savings of up to 18% for single lane and more than 30% for multi-lane. As for mobility, Ahn et al. found that the Freight Signal Priority (FSP) and the Intelligent Traffic Signal System (I-SIG) applications reduced vehicle delays and travel time by 20% and travel time variability by up to 56% for connected trucks.

2.0 METHODOLOGY

The following sections discuss the tasks performed by the research team throughout this study to develop a connected vehicle environment within the driving simulator. This includes also a discussion about the procedures performed to test a possible driver assistance application in the connected vehicle environment. First, the research team went through most recent studies involving connected vehicles test bed in driving simulator environment. This is in addition to other studies about the possible applications of connected vehicles. Second, the simulation network was developed. To enable communication between vehicles, JavaScript coding was performed to allow communication between the simulator and the lead car in the simulation environment. Third, a forward collision visual alerts application was coded into the simulator to test the benefits of that application. Then, test and experimental drives were conducted with and without the visual alerts to test the significance of the system. The required data were collected from the simulator for statistical analysis. Based on the analysis results, conclusions were made. Figure 1 shows a flowchart summarizing these steps.

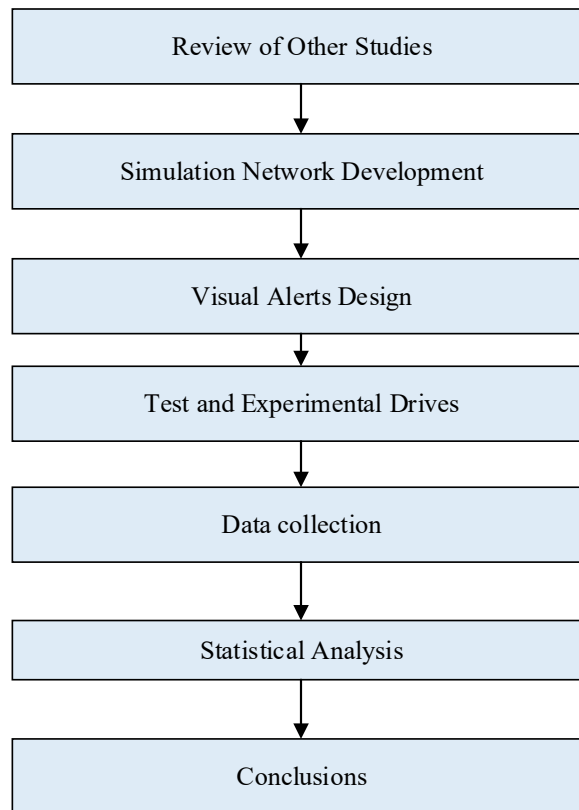


Figure 1: Research methodology

2.1 SIMULATION NETWORK DEVELOPMENT

2.1.1 Driving Simulator Features

The driving simulator at Louisiana State University (LSU), shown in Figure 2, consists of a full-size passenger car modeled after a Ford Focus automobile. The simulator features complicated computer programming that combines with a series of cameras, projectors and screens to provide a high fidelity virtual environment. Three large screens are connected with each other providing a 180-degree front view display. The two side view mirrors of the simulator are electronic cameras providing a real time digital video display for the rear side view of the car in the simulation environment. An additional 4th screen is located behind the simulator; this screen displays a real time video for the rear view of the vehicle within the simulation environment. The rear view mirror in the driving simulator is an ordinary rear view mirror, that is manually adjusted to get the desired angle of view from the rear screen. The simulator has an audio software and hardware plus real time one degree of freedom motion in the forward-backward direction so that participants can drive with engine sound, tire sound and noise from the vehicle. This allows the drivers to interact with the simulator in a realistic simulation environment.

Researchers can select from a variety of weather conditions, road surfaces, driving environments and other options. From then on, the driver is immersed in a world of the researcher's choosing – anything from a rainy, busy interstate to a sunny day in the big city. Once the Participants put the car in motion, driving the simulation is identical to driving a real car. The participants have to put the car in gear, use the mirrors for better visual awareness, and reaction to other vehicles in traffic. The real time one degree of freedom motion in the forward-backward direction imitates real driving conditions by moving the simulator a little bit forward whenever the throttle is applied, making the driver feels the pressure of the seat back on his back. Similarly, when applying brakes but in the other direction, making the driver feel a little the grip of the seatbelt.

Due to the different levels of visual stimulation and simulated movement, vertigo, dizziness and nausea are common after the first drive, which is why participants in any study will have to operate the equipment multiple times before their results can be recorded. These advert effects might still persist for some participants even after several drives. These participants are discouraged to participate in experiments. The simulator is also equipped with an emergency red button to terminate the experiment instantly by the driver, whenever the driver experiences any health problems. This is extremely crucial for the experiments involving severe weather conditions as driving during hurricane, where some of the drivers might experiences dizziness and vomiting.



(a) Simulator body



(b) The computers control

Figure 2: LSU driving simulator

2.1.2 Developing the Simulation Network

The simulator's flexible scenario creation interface and customizable highway system design tools allow for the driving scenarios to be changed based on weather conditions, roadway surfaces and environments, and also allows for other options to be added by the application software SimVista. The dynamics of the simulator itself can be modified by the application software SimCreator; a graphical simulation and modeling system. In addition to those programs, there exist the JavaScript files, scripted vehicle activity in C/C++ code components, and can be used to call up functions during the simulation to either control aspects of SimCreator or the SimVista. Four computers control the simulation, one for setting the experiment parameters and calibrating the steer-wheel of the simulator and the other screens the image that is being captured by the cameras, and two more are used for data analysis. The simulator is able to gather sensing data such as vehicle speed but has not been programmed to collect any data on the ambient traffic. Digital cameras are installed within the vehicle, are linked to the application software, SimObserver, to collect video that is time-referenced with the sensing data. Four digital cameras that feed into the SimObserver are installed in the simulator car, allowing the ability of capturing video from four different angles inside the vehicle and observe the driver's behavior more accurately. Additional data can also be captured for every single frame on top of the video stream such as the vehicle coordinates, speed, acceleration, etc.

The research team used the SimVista application integrating with the driving simulator to develop a simplistic realistic network that consists of an undivided urban four lane roadway. It has a solid double yellow line down the center, solid white lines on the outside edges, dashed white lines separating the two lanes that go in each direction, and on a flat grade with a posted speed limit of 35 mph. The roadway segment was designed to cross several signalized intersections. Clear sunny weather conditions were set as the environmental conditions accompanying this road network.

2.2 CONNECTED-VEHICLE TESTBED DEVELOPMENT

In the following, a profound discussion of the research tasks is presented. The test bed development, the performed coding, the forward collision algorithm, the experimental design, and the analysis are discussed. Before all that, it was important to get some insight about people's expectations and requirements. Thus, a questionnaire was designed to investigate what are people expecting to get out of the connected vehicle technology, how they should deal with the technology, and how should the in-vehicle assistance be designed to minimize any possible distraction, among other issues discussed in the next section.

2.2.1 Public Acceptance and Expectations Survey

Public acceptance is an imperative factor that means that the public are satisfied with a specific technology and accepting it. It is important to ensure a reasonable percentage of public acceptance for any technology prior investing in it. High percentage values of public acceptance indicate higher opportunities for further development in the technology which means higher expectations from the technology. In view of the above, a survey was conducted to measure the acceptance of the people to the technology. However, due to the prior expectations of having very high acceptance percentage, the survey was extended to measure the potential expectations from the

people from such technology and to have a clear idea about the drivers' information requirements that can help them drive in a safer and more operable environment. The survey is intended to address the information requirements in different driving situations. It is also anticipated to address the best way for information presentation and visualization for the driver that can decrease the information processing time by the driver. As such, a questionnaire with 18 questions was designed on "SurveyMonkey" website, and sent out to LSU civil engineering graduate and undergraduate students. The Public Acceptance and Expectations Survey is shown in Appendix A. The responses of 79 participants to each question are analyzed and presented in the following section.

The participants were asked about their acceptance to the technology. The 79 participants expressed their need to have the connected vehicle technology which indicates the importance of the different applications the technology may offer. Then, the participants' need to specific technology applications were investigated. As such, the participants were asked about their need to the signal timing as an important information while approaching a traffic signal. With a 100% response rate, 82.3% of the participants showed their need to have this piece of information in their cars. Based on the participants' responses, the remaining green time information was found to be more important than the remaining red time information.

While approaching an intersection, some drivers may become confused about whether the lane they are occupying is the right lane for their planned movement. This may lead to improper lane changing behavior at the intersection which could cause unnecessary delays. As such, when the participants were asked about their need to the lane use information (whether a lane is assigned to left turn lane only, right turn lane only ... etc.), 81% showed their need to that piece of information while they are approaching an intersection.

Drivers' inattentiveness is a critical issue that could result in traffic violations and lead to traffic accidents in many cases. Unless the distracted drivers receive alerts, they may run a red traffic light, run a stop sign at an intersection, or speed up to beyond the speed limit. These warning alerts are one of the connected vehicle applications. As such, the participants were asked about the signs they usually do not notice and need to have information about while they are driving. The participants' responses, as shown in Figure 3: **Distribution of controller information needs survey**

, indicated that they need to receive alert messages about all the signs they were asked about but with different ratings. The participants rated the importance of all the signs with ratings higher than 3 out of 5. They also proposed to receive information about other signs such as, exit ramps, work zones, and no turn on red signs.

In addition to the drivers' inattentiveness, short sight distances at the intersections is one of the factors that could cause traffic accidents. Vehicles traveling on two intersecting roads may run into one another if they do not have enough time to stop, which could result from either driver's inattentiveness or short sight distance. In such a conflicting-movement scenario, an alert message about a right-angle vehicle coming from an intersecting road can help to reduce the crash risk at intersections. Thereby, the participants were asked about the importance of such warning alerts. Unsurprisingly, 75% of the participants showed their need to these alerts, which indicated the importance of these messages as a safety application of the connected vehicle technology. The

warning alerts about another critical conflicting movement that take place on the interstates was investigated. The participants were asked about the importance of receiving information on the safety of a merging maneuver they are planning to perform while they are entering the interstates. Their answers showed that 77% out of 77 respondents need such information, indicating that most of the drivers may need assistance to perform the merging maneuvers on the interstates.

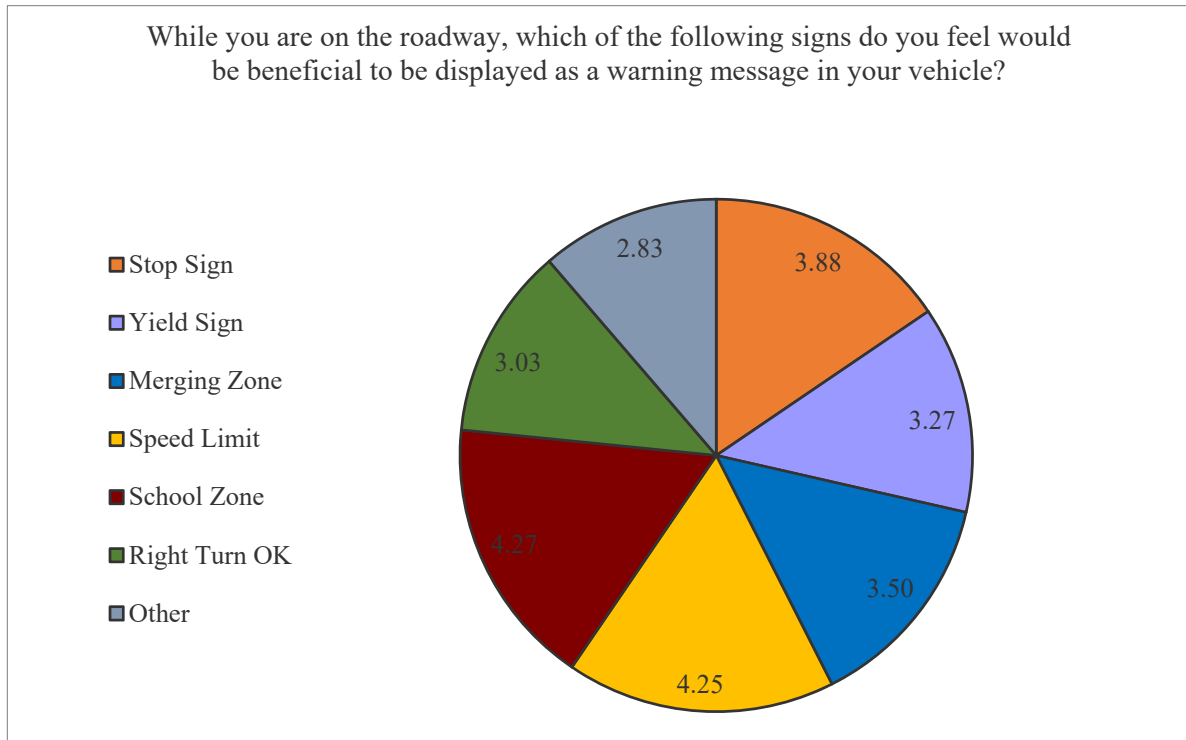


Figure 3: Distribution of controller information needs survey

In addition to safety, connected vehicle technology is aiming at improving the operational characteristics of the transportation networks. One of the operational applications of the technology is the incident-ahead information. Drivers should receive information about the incident locations which could help them make the right decision (re-routing, slowing down ... etc.) at the right time. As such, the participants were asked about the importance of such incident-ahead information. All the participants found this information to be very critical for them, not only to improve the mobility but also, because of the associated safety benefits.

Regarding their ability to process and react to the relayed information, the participants were asked about the amount of information they can handle at a time. Most of the participants expressed their ability to process multiple pieces of information at the same time, with 87% of them thought that two to three pieces of information as the maximum amount they can handle at a time. They also thought that more than 3 pieces of information could represent an overload that might result in unsafe driving environment. The drivers of the equipped vehicles with the connected vehicle technology should receive the information on a display in their cars. This information could be presented in the form of images, text, auditory alerts, or combination of two or more of the previous forms. In order to investigate the optimal form to relay the information to the drivers, the

participants were asked about their ability to process the aforementioned forms. Their responses showed that 80% of the participants found the images to be the easiest form that they can process. Whereas 50% found the auditory alerts to be the second best form, and a low percentage of 33% found the text as a good way for presenting the information. These results are very reasonable as people are better in processing images and audio alerts more than the text, especially while driving at high speeds which can minimize the drivers' distraction.

In addition to the form in which the information could be relayed to the drivers, the in-vehicle location where this information should be relayed could contribute to the drivers' distraction. As such, the participants were asked to choose the best out of three locations where the relayed information should be presented. The three locations are shown in Figure 4: **Location of the information display**

. The participants' responses showed that 42% preferred location one, 34% thought that location two is the best, and only 24% found that location three is better to relay the information. These results agreed with a previous study (Holmes 2014) that suggested that most of the drivers comply with the messages displayed at that location one. The study also identified that location to be the safest for drivers to mount off-the-shelf GPS devices so as to minimize the drivers' distraction.



Figure 4: Location of the information display

2.2.2 Design of the Visual Alerts Message System

The alerts were designed as visual text messages that warned the driver of imminent potential crash with the lead vehicle. The alert messages were designed using the C++ interface of the simulator according to the logic shown in Figure 5.

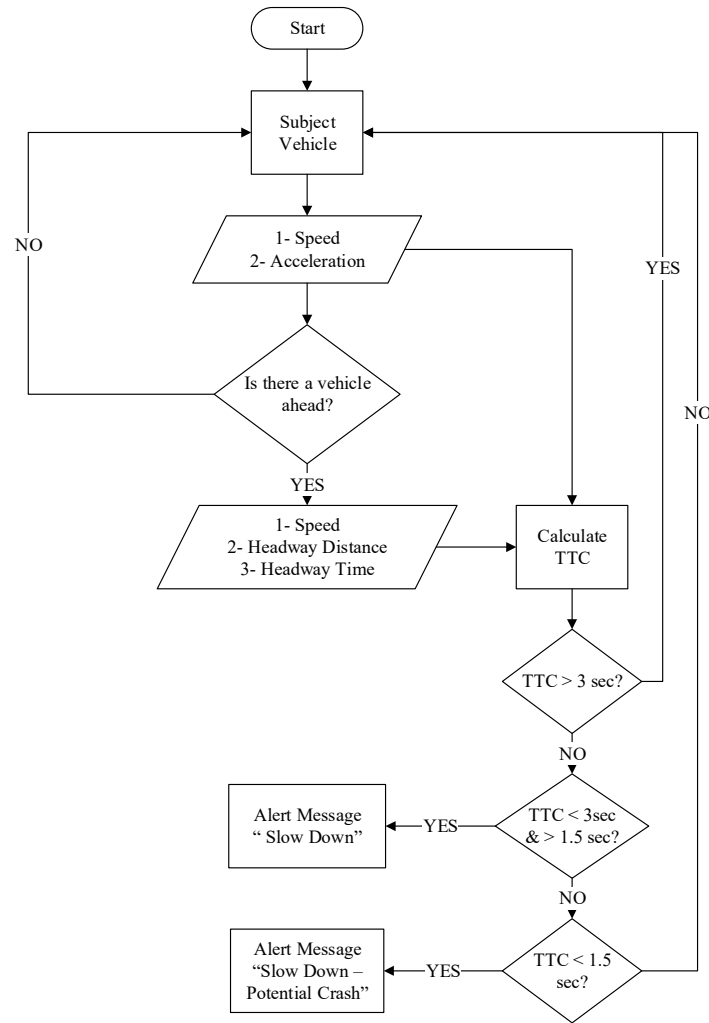


Figure 5: Alert messages logic in C++

Based on Yang and Fliker's (Yang & Fricker, 2001), it was decided to omit auditory warnings because drivers were allowed to become familiar with the scenario surroundings before the actual test. The first of two visual warning messages was projected onto the driver's screen in a yellow font as "SLOW DOWN" when the driver's minimum time-to-collision (TTC) was down to 3 seconds. This is shown Figure 6-a. The second visual warning message, displayed in red font, read "SLOW DOWN- POTENTIAL CRASH" when the TTC further dropped to 1.5 seconds, the minimum TTC required for drivers to safely react (WINSUM & HEINO, 1996). This is shown in Figure 6-b. The generation of these alert messages were programmed using the JavaScript files associated with the driving scenario. For the message size to be readable, a 7" frame that mirrors a HUD was projected onto the middle of the windshield. Three participants were asked to assess

the readability of the projected message inside the frame and the text size was edited until the three drivers agreed that it was clear and readable within the 7” frame. This made the test-bed very close to simulate a connected vehicle HUD.



(a) At 3 seconds threshold



(b) At 1.5 seconds threshold

Figure 6: Alert messages display

2.2.3 Participants

Thirty participants aged between 18 and 58 years of age (mean = 27.3, standard deviation = 8.17), and consisting of five females and twenty-five males were recruited from the Louisiana State University's community of students and staff. They were all of good general health, and were active drivers with a valid driver's license. They were recruited using flyers on university bulletin boards and in accordance with the university's Institutional Review Board's (IRB) standards. No financial incentive or course credit was offered so all subjects participated out of their own interest. To be able to classify them into aggressive and non-aggressive drivers, participants were asked to complete the Larson Driver's Stress Profile (LDSP) questionnaire (Larson, 1997) but were not informed of the criteria so as to not influence the scoring of their driving behavior. The LDSP, shown in Appendix B, was developed by psychiatrist Dr. John Larson for the AAA foundation for Traffic Safety and is a 40-question Likert scale instrument, grouped into four sub-groups of 10 questions each: Anger, Impatience, Competition, and Punishing Behaviors. Participants scored each question on a 0-3 scale (0 = never; 1 = sometimes; 2 = often; 3 = always). Scores were then summed up and participants with a summed score less than or equal to 21 were classified as non-aggressive drivers, while those with greater scores were classified as aggressive drivers. This criterion was selected based on previous studies (BLANCHARD, 2000) and (Malta, Blanchard, & Freidenberg, 2005). Consequently, there were 20 non-aggressive and 10 aggressive drivers from the subject pool. Appendix C presents a summary of the responses of the participants to the Larson Driver's Stress Profile (LDSP) questionnaire. The validity of the LDSP questionnaire for determining aggressive and non-aggressive drivers has been thoroughly analyzed by BLANCHARD (2000) who found the instrument to be "sound, reliable, and valid scale for use with aggressive driving".

2.2.4 Experimental Drives Design and Procedure

The experiment was designed as a pre-post-test study with all thirty participants required to drive the simulator with two test runs. For the base run, each participant was instructed to following his typical driving behavior. As for the second run, the participants were asked to perform the test with the alert message system within the developed test bed scenario. Also for the second run, the participants were requested to respond to the messages displayed as a warning messages. Drives with alert messages resulted in the warning messages being generated as described under 'Design of Alert Message System', while drives without the alert messages did not produce any warning messages.

Upon arrival at the driving simulator lab, participants were briefed on the experiment and asked to review the university's IRB approved consent sheet before signing it. This was then followed by completing the LDSP questionnaire. Participants were then asked to draw a card to determine the order of their drives (with or without alert messages). The drives were randomly determined in order to nullify any learning effect. Each participant was then allowed to practice with the driving simulator until such time that they became familiar with the controls and its operation. The actual test then followed with participants being asked to drive as they would normally on their way to work or college but to always stay in the right-lane, avoid changing lanes or overtaking, and maintain a consistent following distance that they considered as safe.

2.3 DATA COLLECTION AND STATISTICAL ANALYSIS

Data was collected for only when the vehicles were within 20 seconds of approaching an intersection stop line due to earlier studies (Lloyd, Wilson, Nowak, & Bittner, Jr, 1999) suggesting 15 seconds as the minimum time required for drivers to react to warning messages at stop lines. Each participant's velocity (v), lead vehicle's velocity (v_l), and headway distance (D_h) between the participant's vehicle and the lead vehicle for both drives were collected at 60 Hz frequency through the proprietary software of the driving simulator. The time-to-collision for each participant (TTC_i), defined as the time in seconds for the participant's vehicle (of length l) to make contact with the lead vehicle, was calculated for each drive and for all the observations as follows:

$$TTC_i = \frac{D_h - l}{v - v_l} \quad (1)$$

For each participant, the mean value of TTC_i was then computed for each drive so that the final data consisted of one row of data for each participant containing four columns: participant ID; mean TTC for the drive with alert messages; mean TTC for the drive without alert messages; and the difference in means between the TTCs for the two drives. The data were then organized into two separate groups based on aggressive and non-aggressive drivers and analyzed separately.

Because the same participant carried out both drives, the samples were treated as dependent and subjected to a dependent t-test in ANOVA to find whether there were any differences in the driving behavior of the subjects as they were exposed to the alert messages. The paired sample test was appropriate as it did not impose an equal variance assumption on the two drives, and exclusively allots any difference between the mean TTCs for the two drives to the presence of the alert messages. Prior to the t-test, the data was checked for violation of the normality assumption. All statistical analysis was performed using SAS Enterprise Guide 4.3.

3.0 DISCUSSION OF RESULTS

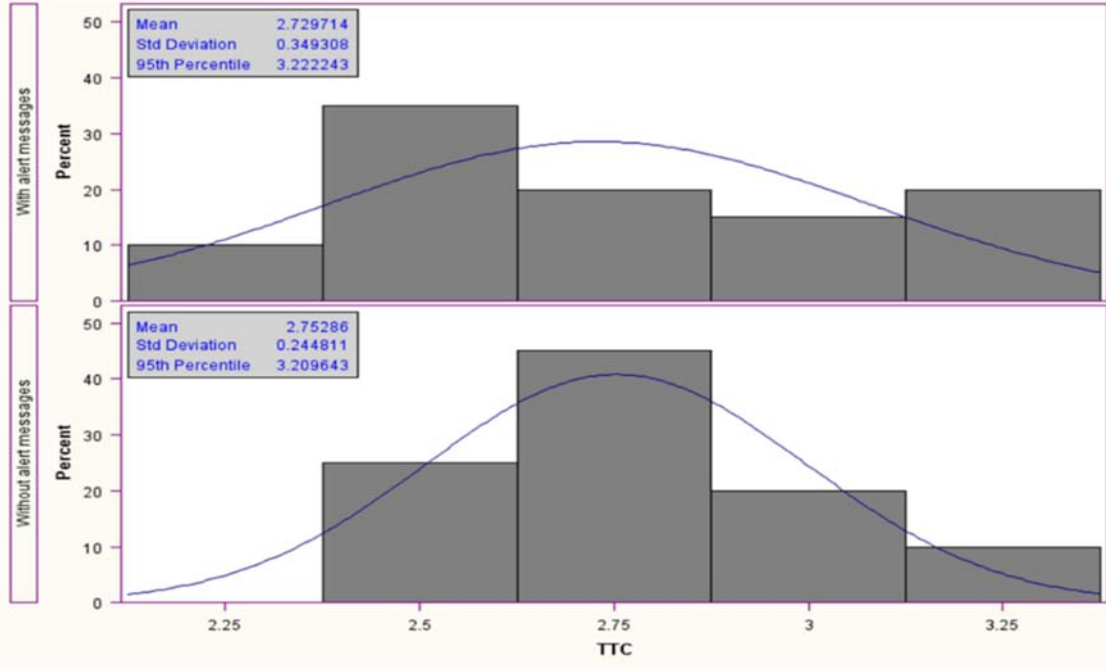
A formal test of the normality assumption was performed for the difference in means between the TTCs for the two drives for all participants. The result (Shapiro-Wilk's statistic = 0.9478, $p = 0.1479$) was not significant at 0.05 level of significance, and hence, failed to reject the normality assumption. This is a required assumption of the t-test for dependent samples.

The t-test for dependent samples was performed separately for the aggressive and non-aggressive drivers. The null and alternative hypotheses tested in each case were:

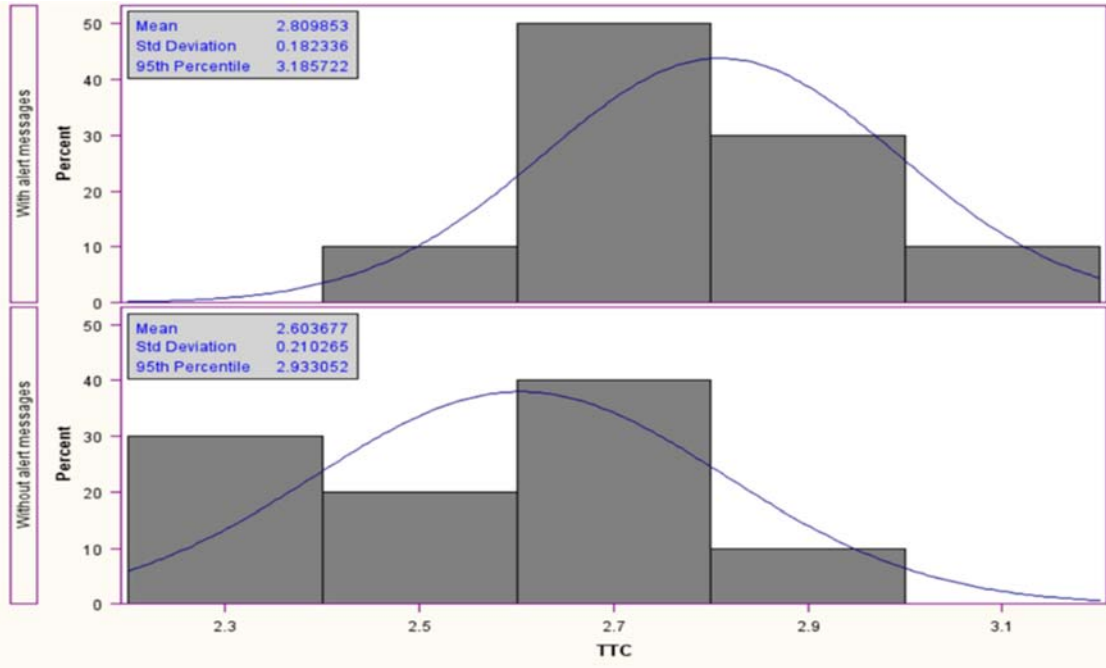
H0: There is no significant difference between the mean TTC observed without and with alert messages.

H1: There is a significant difference between the mean TTC observed without and with alert messages.

Driving runs were done twice per driver. Firstly, drivers are categorized into two groups; aggressive drivers and non-aggressive drivers. Secondly each driver was requested to make a base run with his typical driving behavior and a testing run with warning messages alert. For non-aggressive drivers, the result [$t(19) = -0.32, p = 0.7561$] suggesting we fail to reject the null hypothesis at a 5% level of significance. On the other hand, for aggressive drivers, the result [$t(9) = 2.58, p = 0.0297$] suggests that the null hypothesis can be rejected at the 5% level of significance, leading to the conclusion that the display of alert messages caused a significant difference in the driving behavior of aggressive drivers. Furthermore, Figure 7 shows the profile plots for the two groups of drivers: TTC values for the drives with and without alert messages.



(a) Non-aggressive drivers



(b) Aggressive drivers

Figure 7: TTC profile plot for drivers with and without alert messages

The profile plot for the non-aggressive drivers suggests that while the difference between the drives with and without alert messages was not significant, the mean TTC for the drives with alert messages was slightly lower than the drives without alert messages. This means that for drivers without alert messages, the non-aggressive drivers drove with slightly more caution than they would normally do. Upon analysing their video data, it was obvious that a few of them tended to drive closer to the lead vehicle during the drive with the alert messages. When interviewed, they expressed that they knew they would be prompted by the alert messages when they were too close to the lead vehicle and that influence their driving behaviour.

4.0 CONCLUSIONS

Connected vehicles technology has been acknowledged to have operational benefits in terms of reducing travel times and delays for the traveling public, as well as lessening the environmental impact in terms of reducing vehicle emissions and air pollution. The deployment of such technology offers an opportunity for economic development by targeting improvements in the areas of traffic operation, safety, and environmental impacts. However, to be able to fully assess its reliability and potential benefits, it requires the use of test beds which will additionally address unforeseen and potential issues associated with the development and deployment of the technology. Simulation-based test beds, harnessing a driving simulator platform, can be utilized to achieve the benefits of a physical test bed and if successful, will provide a cheaper alternative that can be easier controlled for desired effects.

For this study, a preliminary driving simulator test bed was developed using the LSU driving simulator and through manipulation of appropriate proprietary software. A survey was conducted to determine where best to display two different alert messages based on the time-to-collision between the simulator and the lead vehicle. A sample of aggressive and non-aggressive drivers were recruited and their driving performance at approaches to intersection stop lines analyzed for differences in drives with the alert messages and drives without. The performance measure used to analyze the drives was time-to-collision since emphasis was on avoiding collisions at intersections. Upon carrying out a t-test for dependent samples for each group of drivers, the results showed that the non-aggressive drivers did not significantly change their driving behavior when exposed to the alert messages. On the other hand, aggressive drivers significantly changed their driving performance by slowing down more at intersections and increasing their time-to-collision. It was also observed that aggressive drivers activated more alerts than the non-aggressive drivers, implying the alert message system was successful in altering their driving style.

The successful development of the preliminary driving simulator test bed means future sensitivity tests can be undertaken to ascertain the optimal moment to prompt the activation of the alert messages. The addition of audio prompts to the current visual alert system can also be explored and a larger sample size can be utilized to analyze demographic effects of such technology. It is acknowledged that the present sample size is a limitation of the study. In addition, other driving characteristics such as speed, acceleration and time headways could be analyzed before and after the alert message in order to investigate potential adaptation effects in driving behavior. Furthermore, the preliminary test bed can be enhanced to allow more vehicles to communicate within the generated network of the driving simulator environment, and further benefits of the V2V technology explored.

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APPENDIX A

PUBLIC ACCEPTANCE AND EXPECTATIONS SURVEY

Can Cars Talk in the Future?

Are you willing to drive in an environment where cars are able to talk to each other? In the near future, cars will be able to send and receive information about traffic conditions. Vehicles can communicate with each other as well as with the infrastructure and this information can be brought to you. This technology could transform the nation's surface transportation safety, mobility, and environmental performance.

The Department of Civil Engineering at LSU has been working on ways to design this technology, in the LSU Driving Simulator. This five minutes survey will help us answer the questions of whether you as a driver would benefit from receiving information to your vehicle, what type of information, and what would be the best way to present it to you. More information can be seen in the following videos, <http://youtu.be/T8iRg5530-8> & <http://youtu.be/ajImRDJIMRU>



***1. If information about traffic conditions, traffic incidents, hazards, congestion, and potential detour routes ahead of you are presented to you on a display in your vehicle would that benefit you?**

- Yes
 No

Can Cars Talk in the Future?

***2. If you are approaching a signalized intersection, would you think it is beneficial to get information about the traffic light timing in your car?**

- Yes
 No

***3. If yes, choose the applicable answers**

	Least Important				Most Important		N/A
Amount of Remaining Green Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Amount of Remaining Yellow Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Amount of Remaining Red Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

***4. Would you want to get information about whether the lane you occupy is a right turn lane ONLY, left turn lane Only, or shared lane presented on a screen in your car?**

- Yes
 No

***5. Please rank how important the lane usage information is to you, with 1 being least important and 5 being very important**

- 1
 2
 3
 4
 5

Can Cars Talk in the Future?

***6. While you are on the roadway, which of the following signs do you feel would be beneficial to be displayed as a warning message in your vehicle?**

	Least Important				Most Important		N/A
Stop Sign	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Yield Sign	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Merging Zone	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Speed Limit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
School Zone	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Right Turn OK	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

***7. While approaching an intersection, do you think it is beneficial to get warning messages on a display in your car telling you whether it is safe to cross or not?**

- Yes
 No

***8. Please rank how important you feel the conflicting vehicle warning information is, with 1 being least important and 5 being most important**

- 1
 2
 3
 4
 5

***9. Would you like to get information displayed on a screen in your car about whether a pedestrian is about to cross the street, displayed as a warning message in your vehicle?**

- Yes
 No

Can Cars Talk in the Future?

***10. Please rank how important the crossing pedestrian information is to you, with 1 being least important and 5 being most important.**

- 1
- 2
- 3
- 4
- 5

***11. At an interstate, would you find it beneficial to know whether it is safe to merge at the end of on-ramps presented on a display in your car?**

- Yes
- No

***12. Please rank how important the on-ramp safe merging information is to you, with 1 being least important and 5 being most important.**

- 1
- 2
- 3
- 4
- 5

***13. Would you find it beneficial to receive and display in your vehicle, any information about a traffic incident ahead of you, and to know potential detour routes?**

- Yes
- No

Can Cars Talk in the Future?

***14. Please rank how important the incident information is to you, with 1 being least important and 5 being most important**

- 1
- 2
- 3
- 4
- 5

***15. Based on your previous answers, do you think you are able to react to more than one piece of information at the same time?**

- Yes
- No

***16. How much information? (Specify how many pieces of information)**

Can Cars Talk in the Future?

Shown are four potential display locations in your vehicle.



***17. Which location from the above image is preferred?**

- 1
- 2
- 3

***18. How would you like information to be given to you?**

- Images
- Numbers
- Audio Alerts

The Department of Civil Engineering at LSU would like to thank you for participating in our survey. If you would like to participate in experiments with the LSU Driving Simulator to test new technology, please put your contact information in the comment box below. Thank You.

APPENDIX B

**LARSON DRIVER'S STRESS PROFILE (LDSP)
QUESTIONNAIRE**



Are YOU an Aggressive Driver?

Take the Driver Stress Profile to Measure Your Hostility on the Road.

LARSON DRIVER'S STRESS TEST HAS BEEN REPRINTED WITH PERMISSION FROM AAA FOUNDATION AND DR. JOHN LARSON

Enter the appropriate number in the boxes as it applies to you.

never = 0
sometimes = 1
often = 2
always = 3



HOW DO YOU RATE?

ANGER
low = 0-9
medium = 10-14
high = 15+

IMPATIENCE
low = 0-9
medium = 10-14
high = 15+

COMPETING
low = 0-4
medium = 5-9
high = 10+

PUNISHING
low = 0-4
medium = 5-9
high = 10+

ANGER

- Get angry at drivers.
- Get angry at fast drivers.
- Get angry at slow drivers.
- Get angry when cut off.
- Get angry at malfunctioning stoplights.
- Get angry at traffic jams.
- Spouse or friends tell you to calm down.
- Get angry at tailgaters.
- Get angry at your passengers.
- Get angry when multilane highway narrows.
- Total**

COMPETING

- Compete on the road.
- Compete with yourself.
- Compete with other drivers.
- Challenge other drivers.
- Race other drivers.
- Compete with cars in tollbooth lines.
- Compete with other cars in traffic jams.
- Compete with drivers who challenge you.
- Compete to amuse self when bored.
- Drag race adjacent car at stop lights.
- Total**

IMPATIENCE

- Impatient waiting for passengers to get in.
- So impatient, won't let car engine warm up.
- Impatient at stoplights.
- Impatient waiting in lines (car wash, bank).
- Impatient waiting for parking space.
- As passenger, impatient with driver.
- Impatient when car ahead slows down.
- Impatient if behind schedule on a trip.
- Impatient driving in far right, slow lane.
- Impatient with pedestrians crossing street.
- Total**

PUNISHING

- Do you "punish" bad drivers?
- Complain to passengers about other drivers.
- Curse at other drivers.
- Make obscene gestures.
- Block cars trying to pass.
- Block cars trying to change lanes.
- Ride another car's tail.
- Brake suddenly to punish tailgater.
- Use high beams to punish bad driver.
- Seek personal encounter with bad driver.
- Total**

COMPLETE CONTEST BALLOT ON OPPOSITE SIDE

Working
TOWARD
Wellness
at DCCI

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IN PARTNERSHIP WITH DCCI AND THE CAW.

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CANADA

ANGER

In certain circumstances, you may feel like you lose self-esteem or status by giving in and allowing a demanding driver to get his/her way. If the driver continues in the attempt to pass or cut you off, a dangerous situation may occur. Anger results when this type of behaviour persists, escalates or if the other driver succeeds.

You will be much happier if you learn to enjoy your journey instead of letting yourself grow angry over petty road behaviour. Be relaxed, listen to some soothing music or have a nice conversation with your passengers. When you think of driving, whether it is to work every day or on your vacation, don't think of it as wasted time. Instead, relax and think of driving as worthwhile and pleasurable.

Plan ahead and allow yourself plenty of time to drive comfortably to your destination. This will allow you to deal with unforeseen situations like traffic jams that may set you back. Remember that if you are looking for drivers to yell at and cars to cut off, you will find them.

KEY REMINDERS TO CONTROL YOUR ANGER

- If another driver cuts you off or races by, program your response to be "Be my guest."
- Instead of making good time, make time good!
- If you're tempted to retaliate against another driver, think: "Would I want to fly in an airplane whose pilot was acting like this?"
- Instead of judging the other driver, try to imagine why he or she is driving that way.

IMPATIENCE

When you begin to feel your blood boil, give the other drivers the benefit of the doubt and treat them how you would like to be treated. This will make for a more pleasant driving experience.

If you approach driving with an attitude of willingness to cooperate and accommodate other drivers. You will be a much safer driver.

If you think another car is driving too slowly and you are unable to pass, pull back and allow more space, not less. That way, if the car does something unexpected you will have time to get out of the way. If you attempt to pressure the driver in front of you by following as closely as possible, an accident is much more probable.

KEY REMINDERS TO IMPROVE YOUR PATIENCE

- Don't get mad at people who go the speed limit. It's the law, and everyone should follow it.
- Allow at least a two-second space between your car and the car ahead.
- When growing impatient with a driver, act as if he or she is a guest in your home.

COMPETING

There are plenty of times and many other places to partake in games, but on the road is not one of them. For too many motorists on the road today, driving has become a contest.

The most important actions you can take to avoid aggressive and competitive driving take place inside your head. Change your approach to driving to make your trips more enjoyable. If you insist on playing a game, see how nice you can be to other drivers.

When you begin to speed and pass other drivers on the highway because of a game only you are playing, ask yourself, "Is this worth dying for?" Highways are too dangerous for games.

KEY REMINDERS TO FORGET BEING COMPETITIVE

- The more you speed, the less you experience your surroundings.
- Enjoy the ride with your companions. If you race and compete you may actually upset yourself and your passengers.
- Instead of thinking that winning is everything, start to think that making it to your destination safely is the only thing that matters.
- Allow more time for your trips. You'll be amazed at how much more relaxed you will be when you have a few extra minutes.

PUNISHING

It is rarely helpful to other drivers, yourself and least of all your passengers, for you to assume the responsibility of punishing other motorists. This is a job that should be left to the police. Attempting to take things into your own hands is likely to inflame the situation and put you and your passengers at risk.

Change your attitude toward other drivers' aggressive driving habits. Keep in mind that they are likely not motivated by personal intention to harm, threaten, or endanger you. They may be inattentive, forgetful, extremely fatigued or have bad driving habits.

Punishment, coming from someone who really has no authority in the matter, is not perceived as punishment by the other driver. Instead, they will perceive it as "sticking your nose in their business."

KEY REMINDERS TO STEER CLEAR OF PUNISHING

- Punishing other drivers will only aggravate them more.
- If you believe another driver is attempting to start a fight, immediately get help. Do not get out of your car and do not go home.
- Being annoyed at other drivers' bad driving habits can only happen if you let it. You can't control other drivers. You can only control your reaction to them.
- If you notice an aggressive driver, pull over safely and take down as much information as you can including details of the situation and vehicle information. Then call the local non emergency police services number to report this information.

Once you have completed and filled out this entry form, cut and place in a ballot box located in one of the canteens.

1. Based on your driver stress profile what is one habit you need to work on?

2. Identify one driving habit that you have that shows courtesy to other drivers.

Name _____ Phone _____ Master # _____

APPENDIX C

PARTICIPANTS' RESPONSES FOR LDSP QUESTIONNAIRE

Driver ID	1-10	11-20	21-30	31-40	Age	Gender	Anger	Competing	Impatience	Punishing
1	12	2	3	2	31	M	Medium	Low	Low	Low
2	5	0	2	0	19	F	Low	Low	Low	Low
3	18	4	8	4	35	M	High	Low	Low	Low
4	17	17	22	7	58	M	High	High	High	Medium
5	8	3	7	13	20	M	Low	Low	Low	High
6	17	1	9	2	36	M	High	Low	Low	Low
7	15	5	7	7	33	M	High	Medium	Low	Medium
8	8	7	10	7	29	M	Low	Medium	Medium	Medium
9	10	1	16	7	40	M	Medium	Low	High	Medium
10	12	3	5	7	24	M	Medium	Low	Low	Medium
11	6	3	6	7	22	M	Low	Low	Low	Medium
12	7	9	7	2	25	M	Low	Medium	Low	Low
13	13	3	9	6	36	M	Medium	Low	Low	Medium
14	11	4	8	1	22	M	Medium	Low	Low	Low
15	7	3	10	11	27	M	Low	Low	Medium	High
16	2	4	5	2	25	M	Low	Low	Low	Low
17	9	0	9	2	20	M	Low	Low	Low	Low
18	12	9	12	11	20	F	Medium	Medium	Medium	High
19	13	1	20	5	28	M	Medium	Low	High	Medium
20	9	1	4	3	28	F	Low	Low	Low	Low
21	6	9	13	8	30	M	Low	Medium	Medium	Medium
22	8	0	6	1	22	M	Low	Low	Low	Low
23	11	4	10	7	22	M	Medium	Low	Medium	Medium
24	11	0	3	3	18	F	Medium	Low	Low	Low
25	11	0	7	1	26	M	Medium	Low	Low	Low
26	7	1	13	4	29	M	Low	Low	Medium	Low
27	10	1	7	1	29	M	Medium	Low	Low	Low
28	8	3	11	5	20	F	Low	Low	Medium	Medium
29	12	12	11	10	22	M	Medium	High	Medium	High
30	7	8	2	2	22	M	Low	Medium	Low	Low