DEVELOPMENT OF THE PRE-REAR END POSITIONING AND RISK EXTENUATION SYSTEM (PREPARES)

Alexis Basantis
Virginia Tech
Email: basantis@vt.edu

Alexandria Rossi-Alvarez
Virginia Tech
Email: alexandria@vt.edu

Adam Novotny
Virginia Tech
Email: novotnyaj@vt.edu

Eric Bloomquist
Virginia Tech
Email: erictb7@vt.edu

Richard Greatbatch
Virginia Tech
Email: rlg1990@vt.edu

Luke Riexinger
Virginia Tech
Email: luker7@vt.edu

Samantha Haus
Virginia Tech
Email: shaus@vt.edu

Phillip Grambo
Virginia Tech
Email: phillip8@vt.edu

Zachary Doerzaph
Virginia Tech Transportation Institute
Email: zdoerzaph@vtti.vt.edu

INTRODUCTION

In 2017 there were approximately 2 million rear-end collisions in the U.S. alone. Of the struck vehicles, an estimated 12,880 drivers experienced a serious injury. Currently, automotive manufacturers are pushing boundaries to develop and implement technologies aimed at eliminating or reducing the severity of vehicle crashes such as automatic emergency braking (AEB) and forward collision warning (FCW). Most safety systems developed for collisions are implemented to aid the striking vehicle while limited systems have been developed to mitigate injury of occupants of the struck vehicle. Through the application of agile research techniques, we developed and evaluated a new proof of concept safety system, the Pre Rear-End Positioning and Risk Extenuation System (PREPARES), which is aimed at protecting the occupants of a struck vehicle in an unavoidable, stationary, rear-end collision.

Original Equipment Manufacturers (OEMs) have developed safety systems to help mitigate injuries of occupants resulting from crashes. For example, Mercedes-Benz has developed the PRE-SAFE System, which is designed to automatically trigger safety mechanisms in the seat in the event of an imminent collision. The PRE-SAFE system is designed to reduce any slack in the seat belts, move the front passenger seat to a predetermined upright position, inflate the side bolsters, and close the windows (Bogenrieder, Fehring, & Bachmann, 2009). However, this system, along with most other implemented safety systems, focuses on the striking vehicle, not the struck vehicle.

Many vehicles use auditory cues to alert vehicle occupants that an important event is imminent. Due to the single modality of these cues, they can confuse the driver and cause a communication breakdown, which can lead to a decrease in the driver's performance. Cueing the driver with both an auditory tone and a short, concise visual cue via a Heads-Up Display (HUD) has been shown to be effective in communicating a message to the driver. The dual-modality warning quickly captures vehicle occupants' attention and gives them the ability to effectively intervene (Lau, Harbluk, Burns, & El-Hage, 2018). Furthermore, the use of auditory stimuli in collision warning systems have shown efficiency in re-directing attention back to the road, whereas visual stimuli are more effective in directing attention towards specific objects on the road (Dettmann & Bullinger, 2017). Although the combination of auditory and visual stimuli in dual-modality HUD systems have shown success in communicating necessary information as well as properly directing attention, they are generally utilized to inform the driver of the striking vehicle.

The research team analyzed relevant crashes in the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study to understand the parameters of the intended use case. In SHRP 2 there were 34 cases in which the subject vehicle impacted a stopped vehicle. The median impact speed was 22 mph. In 70.6% of the cases, the vehicle braked before impacting the vehicle with a median deceleration of 0.5g.

The PREPARES system takes a novel approach to alerting the occupants of a stationary vehicle that they are going to be struck. While stationary, there is a higher risk of drivers engaging in secondary tasks causing them to be out of a standard body position which increases the chance and severity of soft tissue damage (Viano & Gargan, 1996). The goal of PREPARES is to rapidly redirect the occupant's attention via a multimodal cue in a manner which elicits the standard seating position in the milliseconds prior to impact, reducing the incidence of whiplash and other soft tissue injuries. To evaluate PREPARES, a research study was conducted to address the following questions:

1) Will the sensor unit and algorithm accurately predict an imminent rear-end collision?
2) What are drivers' reaction times to the system stimuli?
3) Does light frequency have an effect on drivers' reaction time?
4) Does sound frequency have an effect on drivers' reaction time?
5) Do drivers naturally change their body position when the system is activated?

METHODS

Sensor Unit

The sensor unit contains an array of sensors including: two corner radar sensors, one rear facing radar sensor, GPS, inertial measurement unit (IMU), LiDAR, and video camera (Figure 1). The information from these sensors is recorded by the FlexDAS system, a data acquisition system developed at Virginia Tech, and managed with a laptop using Robotic Operating System (ROS).

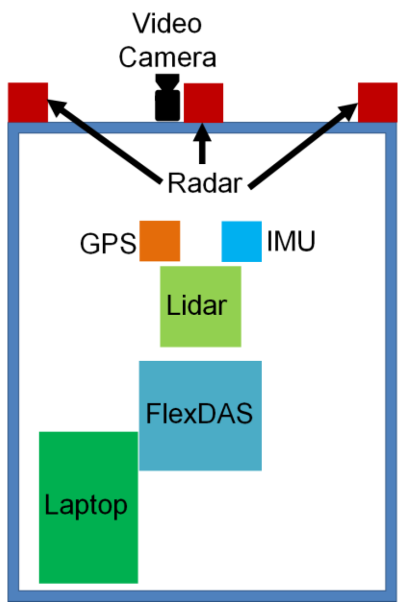

Figure 1. Sensor unit layout.

Algorithm Development

We developed an algorithm to predict the stopping distance of an approaching vehicle using instantaneous data samples for a real time implementation. The algorithm is a 2-part piecewise construction that uses tunable parameters as well as radar data to predict when a collision will occur. The first segment assumes that the oncoming vehicle is moving at a constant speed, measured by radar, with a constant jerk rate of -10.7 m/s^3 (Bagdadi & Várhelyi, 2011). The length of the time window for the first segment is a tunable parameter that we approximated as 0.2s based on reviews of SHRP 2 crash data. The second time window assumes a constant deceleration rate of 0.4g until either the vehicle stops or there is a collision. The algorithm solves for the time at which velocity is zero, finds the corresponding predicted travel distance at that time, and compares the predicted travel distance to the measured distance. Test data of an approaching vehicle is shown below in Figure 2.

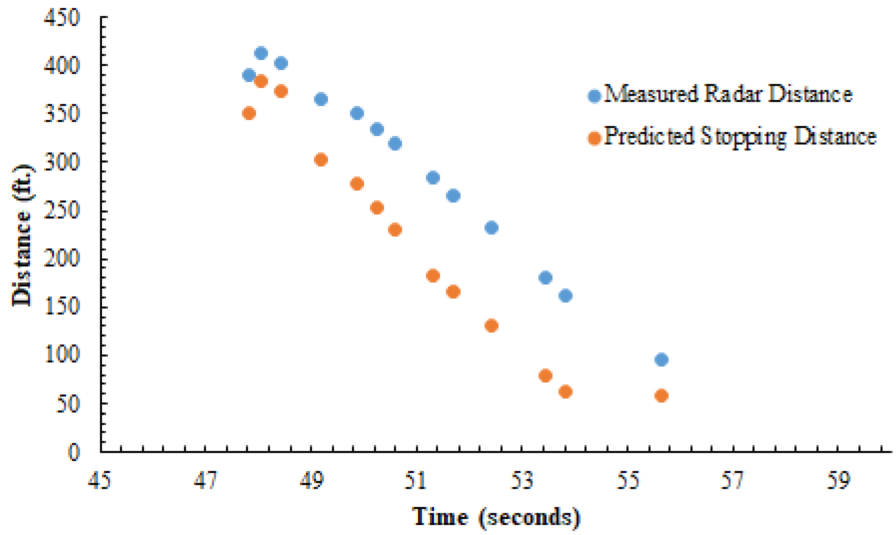

Figure 2. Measured distance and corresponding predicted stopping distance of an oncoming vehicle measured detected by radar and evaluated by our algorithm.

Display Interface

The interface consisted of a multimodal design that simultaneously presented a visual cue and an audio cue for a duration of 2 seconds. The visual cue was presented through an LED panel strip located along the top of the windshield, centered with the driver seat. The visual cue was presented in either a flashing or constant pattern for a duration of 2 seconds. The flashing pattern had a frequency of 5 Hz. The audio cue consisted of sine wave of 3000 Hz that was presented in a pulsed or constant pattern for 2 seconds via a mini speaker located in the same position as the visual cue. To overcome anticipated environmental noises from driving on the road as well as the engine, the sound level of the auditory signal was set at 70 dB. The prototype user interface components are shown in Figure 3.

Figure 3. Interface System

Controlled testing

Sensor Validation

The radar sensors were validated through a series of static tests conducted on the Surface Street Expansion portion of the Virginia Tech Transportation Institute (VTTI) Smart Road, a controlled access test track. The sensor unit was placed at a fixed location and cones were placed at measured distances of 50, 100, 150, 200, and 250 feet away from the unit. A driver in a test vehicle started at the farthest cone and traveled to the closest cone, pausing at each intermittent cone for about 5 seconds. These tests were performed both with the vehicle straight behind the sensors and at offsets to the left and right of the sensor unit. The recorded data was analyzed and compared to the known measurements to confirm sensor accuracy.

Algorithm Testing

Dynamic tests, conducted on the Surface Street Expansion portion of VTTI's Smart Road, were used to test and refine the developed algorithm. These tests used cones to mark out calculated braking zones, where the vehicle should begin to brake, and swerve zones, where the vehicle should begin to swerve if not already fully stopped, according to each speed. A safety buffer zone was also built in to these zones to ensure there would be no collisions with the sensor unit. After collecting real-world data, a corresponding offset was applied to the data points by the algorithm, to simulate a collision. In addition, the test vehicle drove past the left and right sides of the sensor unit, without stopping, and directly behind the unit in a cross-traffic scenario to examine how the algorithm would respond to near-miss situations.

Interface Testing

The multimodal interface was tested using 36 naive participants (female = 23) sitting in a stationary vehicle in a garage bay at VTTI. There were four variations of this multimodal warning signal: constant visual cue/constant auditory cue, pulsed/flashing, pulsed/constant, constant/flashing. Each participant only experienced one of these conditions, which was randomly assigned prior to the session.

The experimental session required the participant to complete four trials where they were asked to perform a secondary task (i.e., sorting a bowl of candy) in three different locations of the vehicle: on the floor in front of the back seat, the front passenger seat, and the center console. Locations were counterbalanced and randomized across participants. The first trial across all participants was the "surprise" condition, which aimed to capture participants' naive response to the multimodal warning signal. While the participant performed the task, the researcher triggered the interface, noted the participant's reaction, and surveyed their opinion about the experience. After the surprise trial, participants were then instructed that the system was designed to direct their attention out of the front windshield and instructed on how to properly respond to the triggered interface in order to calculate their absolute reaction times. After all trials, surveys were distributed to gauge participants' thoughts about the system.

Overall, the purpose of the participant testing was to determine which combination of auditory and visual cues, confounded with body positioning, most effectively captures the participant's attention and repositions them into the proper pre-collision seating position. In addition, the reaction times for the participants were measured to influence the delay timing of the sensor unit algorithm that triggers the interface.

SYSTEM SAFETY ANALYSIS

Hazard Analysis

A hazard analysis (HA) is a "bottom-up" approach of investigating potential hazards of a system. Since the system that we are creating is experimental, a HA would allow us to brainstorm hazards and potential solutions before they occur. In addition, by performing a HA we are also able to calculate the probability of generated hazards and the level of impact they would have on a user, known as a hazard risk index (HRI). In total, 31 potential hazards and recommendations were created.

#	Control Number	Hazard Description	Potential Causal Factors	Potential Effects	HRI (Final)	Hazard Control Recommendation	Effect of Recommendation
1	1.1	LED light fails to activate	Failure to receive information from algorithm, incorrect information given by algorithm, LED bulb burns out, LED light housing breaks	User is not alerted to rear-end collision, user does not reposition body, injury	D3	Add multiple LED lights, test algorithm-->LED connection vigorously before production	Redundancy of lighting
2	1.2	Speaker fails to emit tone	Failure to receive information from algorithm, incorrect information given by algorithm, speaker breaks	User is not alerted to rear-end collision, user does not reposition body, injury	D3	Add another connection to other speakers in the vehicle. Test before production.	Tone may not localize correctly.
4	2.1	TTC calculations are not accurate	Original test data was erroneous, incorrect calculations by algorithm	Interface engages without threat of collision, interface does not engage	E2	Inform the driver that the system is not working properly, and bring car in for maintenance	Forces user to bring the car to the dealer
5	2.2	Braking profiles are not accurate	Original test data was erroneous, incorrect calculations by algorithm	Interface engages without threat of collision, interface does not engage	E2	Inform the driver that the system is not working properly, and bring car in for maintenance	Forces user to bring the car to the dealer

Figure 4. A subset of hazards generated through HA.

The hazard analysis (Figure 4) showed that for a successful system all three subsystems must work in synchronization, and if a hazard occurs, most likely it is due to one or more components failing.

Causal Map Analysis

A causal map analysis (CMA) is a tool for system risk and reliability that we selected to analyze failures seen in the sensor array subsystem. This method allowed us to examine the failure in depth while considering what different effects it could have on different outcome areas. We based this analysis on an issue we experienced with the sensor system in November 2018 where throughout our validation testing, the sensors were not producing the expected data outputs.

The sensor system is the most critical point of failure since the entire system cannot function and the interface cannot trigger if there is no approaching vehicle data. Potential solutions for avoidance are better understanding the specifications and limitations of the hardware, ensuring all wiring is correct, and performing initial, small-scale test trials to confirm working sensors and accurate data collection. Examples of this analysis are located in the appendix.

Fault Tree Analysis

Fault tree analysis (FTA) is a powerful system safety method because it allows visual modeling of complex system relationships, making it ideal for analysis of software. We applied this method to the algorithm subsystem of PREPARES (Figure 5).

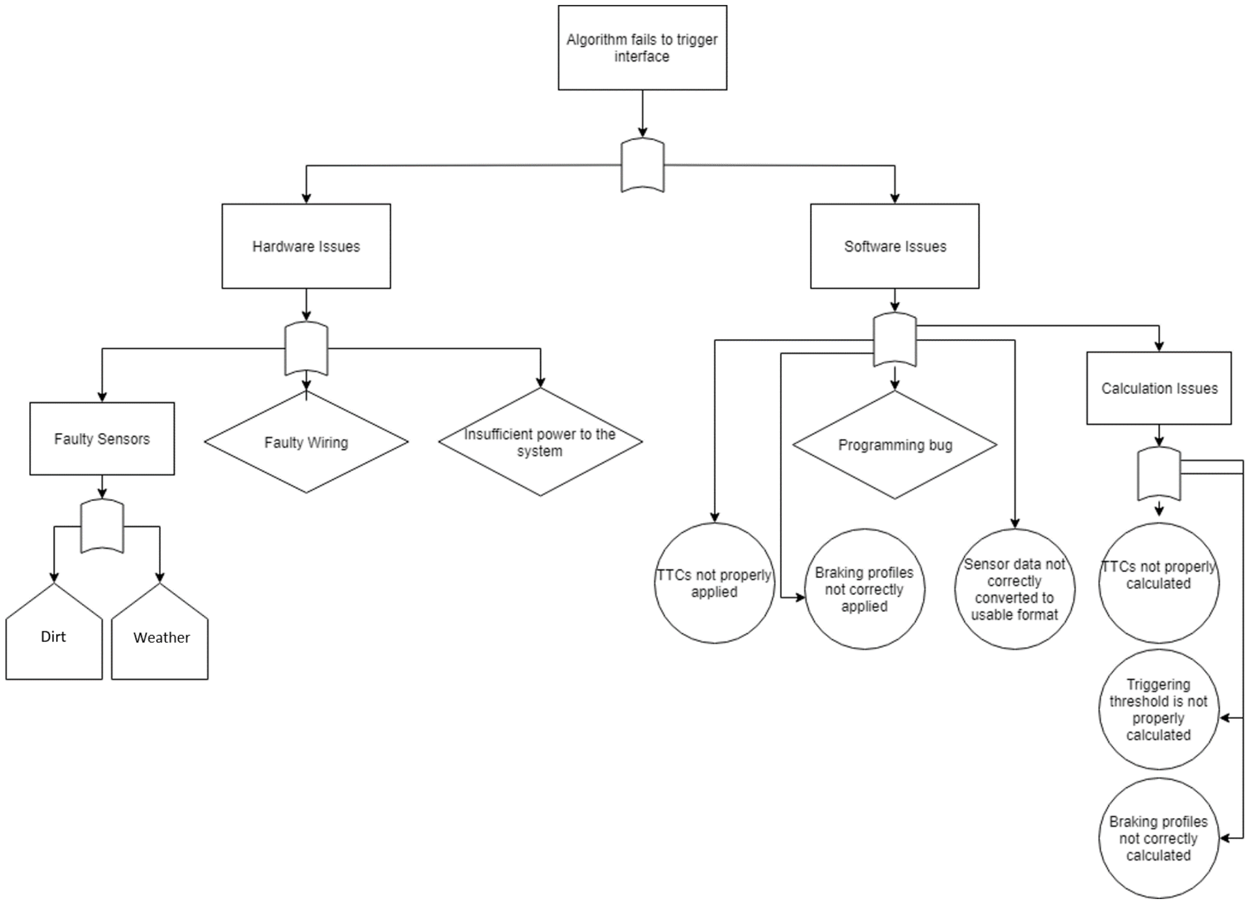

Figure 5. FTA for the PREPARES algorithm

From this analysis we can see that the software component of the system is the most varied point of failure, but also the most difficult to identify. Because of its criticality, it will be necessary in future iterations of PREPARES to not only perform robust benchtop testing of the software but also build in redundancy or system state indicators.

Barrier Analysis

Barrier analysis is a rapid assessment tool which is used to identify determinants of behavior change among a specific target audience. This method is directly applicable to the interface subsystem of PREPARES since it directly affects vehicle occupant behavior (e.g. taking their attention away from the distracting, secondary task and focusing it back on to the roadway).

This analysis confirms that the interface components (light and sound) are the two main barriers to eliciting the appropriate user response. The stimuli must be distinct enough to stand out against external environmental noise and the salience of each component must be high enough to capture user attention.

RESULTS

Reaction times

Reaction times were determined for the “surprise” condition trials. In the surprise trials, 72% of the participants reacted to the interface and 58% of those repositioned into the standard seating position. As shown in Table 1, reaction times varied by location of the sorting task with the passenger seat having the fastest average initial reaction time of 0.723 seconds and the center console having the slowest average initial reaction time of 1.233 seconds. The back-seat bucket location had the slowest reaction time to a proper seating position with an average reaction time of 2.022 seconds. The overall average reaction time to achieve proper seating position was 1.55 seconds.

When comparing the responses to the various interface conditions, the constant visual and pulsed audio interface condition had the greatest number of participants, 6 out of 9, that achieved the proper seating position. Against expectation, the interface condition that consisted of a flashing visual and pulsed audio cue had the smallest number of participants, 2 out of 9, that achieved the proper seating position.

Table 1. Reaction times for the surprise trial by bucket location.

Average reaction times across body positions				
Sorting Location	**Initial Reaction to Interface**	**St. Dev.**	**Proper Seating Position**	**St. Dev.**
Passenger seat	0.723s (n=10)	0.416	1.258s (n=8)	0.692
Center console	1.233s (n=8)	0.589	1.767s (n=4)	0.224
Back	1.192s (n=8)	0.255	2.022s (n=3)	0.713

Qualitative Analysis

The following are summarized, insights from participants feedback during the study. Themes were concluded when 25% of the tested population feedback had agreed (minimum of 9 participants), or they had similar insights. These insights are from preliminary data that has not been fully analyzed. Counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated.

For the surprise trial, participants experienced confusion when the noise (27/36) and light (28/36) were initiated because they did not understand what caused it to alert. Due to the lack of information informing the participant, some participants re-positioned their body forward in confusion (15/36), some moved their head to look up (11/36), while some did not stop sorting starburst (10/36).

A few participants successfully guessed that they system was alerting them that a vehicle was going to hit them (5/36), while other thought it was informing them they were going to strike something (11/36).
Overall, participants thought the sound was more necessary than the light because they noticed it from each position (31/36). Most preferred the sound because it informed the something was happening (28/36). Across all positions, participants were able to hear the alert. Their thoughts on the usefulness of the light changed depending on their body position.

The system was generally desirable to participants because they want more safety features to be provided to them (16/36). Some did not find the system desirable because they did not understand its purpose (8/36). Once participants were provided an explanation about the system, most stated that it was more desirable (28/36). Most participants thought the system should be explained to them via some sort of training (22/36).

DISCUSSION

The efficacy of PREPARES relies heavily on two major components of the system: the sensor unit and the interface. In order to trigger the interface, the sensor unit needs to be capable of accurately detecting an incoming vehicle and calculate, through the implementation of an algorithm, that a collision is inevitable. When comparing the experimental data collected by the sensor unit to the actual distance of the vehicle per the testing procedure, the sensors accurately determined the distances of objects. The matching of experimental data confirms validity of the sensor unit.

Dynamic closed-course trials of a vehicle approaching the sensor unit showed what the data would look like. While we were unable to integrate the collision prediction algorithm online in time for this report, we were able to save the data and refine the algorithm against the sample data, and predict likely collisions.

The interface testing provided valuable provided valuable information on the effectiveness of the PREPARES system. Our study was limited in that it only focused on the driver, other passengers and their reactions to the system were not considered. Additionally, our study was conducted in a garage bay with controlled lighting. In the future, we could improve ecological validity by testing in variable lighting conditions, with variable ambient noise, and on a test track with the participant controlling a vehicle with a fully integrated PREPARES system.

The average time that it took participants to move into the standard seating position was 1.55 seconds. It should be noted that the conditions tested were worst case scenarios. In a real driving scenario, the drivers may not be as out of position or engrossed in their secondary task which would improve their reaction times. Many rear-end collisions occur when the struck vehicle is not stationary. In the future we would like to expand our system to include non-stationary vehicles.

CONCLUSION

The procedure outlined in this paper describes the development and testing of a physical proof of concept that permitted sensor selection and initial tuning of the algorithm and interface for reducing injuries of the victims in rear-end collisions. This safety system is the first system that repositions occupants through a passive warning system. Further testing is needed, but our participant interface testing showed that most participants responded to the system and 42% of participants returned to the standard seating position. These results are promising as the interface was able to passively move naïve participants into the standard seating position.

REFERENCES

Audi Automotive Group. (2011). “The driver assistance systems from Audi: New concepts for safety, convenience and light”. *Audi USA Newsroom*.

Bagdadi, O., & Várhelyi, A. (2011). “Jerky driving - An indicator of accident proneness?”. *Accident Analysis & Prevention*, 43(4): 1359-1363.

Bogenrieder, R., Fehring, M., & Bachmann, R. (2009). “PRE-SAFE in rear-end collision situations”. *The 21st International Technical Conference on the Enhanced Safety of Vehicles Conference (ESV), Stuttgart, Germany*.

Biondi, F., Strayer, D. L., Rossi, R., Gastaldi, M., & Mulatti, C. (2017). “Advanced driver assistance systems: Using multimodal redundant warnings to enhance road safety”. *Applied ergonomics, 58*, 238-244.

Dettmann, A., & Bullinger, A. C. (2017). “Spatially distributed visual, auditory and multimodal warning signals–A comparison”. *Proceedings of the Human Factors and Ergonomics Society Europe*, 185-199.

Farmer, C. M., Wells, J. K., & Werner, J. V. (1999). “Relationship of head restraint positioning to driver neck injury in rear-end crashes”. *Accident Analysis & Prevention*, 31(6), 719-728.

Kistipadu, R. (2017). “Effect of reactive car seats and active head restraint system in rear-end collision and safety mechanisms to reduce whiplash injuries”. *Doctoral dissertation, Wichita State University*.

Koji, K., Koshir, O., Satoshi, I., Koichiro, H. (1999). “Motion Analysis of Cervical Vertebrae During Whiplash Loading”. *Spine*, 24(8): 763-769.

Kullgren, A., & Krafft, M. (2000). “Influence of airbags and seatbelt pretensioners on AIS1 neck injuries for belted occupants in frontal impacts” (No. 2000-01-SC09). *SAE Technical Paper*.

Lau, C. P., Harbluk, J. L., Burns, P. C., & El-Hage, Y. (2018). “The Influence of Interface Design on Driver Behavior in Automated Driving”. *CARSP: The Canadian Association of Road Safety Professionals*.

Lee, J. D., McGehee, D. V., Brown, T. L., & Reyes, M. L. (2002). “Collision warning timing, driver distraction, and driver response to imminent rear-end collisions in a high-fidelity driving simulator”. *Human factors*, *44*(2), 314-334.

McConnell, W., Howard, R., Guzman, H., Bomar, J. (1993). "Analysis of Human Test Subject Kinematic Responses to Low Velocity Rear End Impacts". *SAE Technical Paper 930889*.

National Center for Statistics and Analysis. (2017). “2016 fatal motor vehicle crashes: Overview”. *Traffic Safety Facts Research Note*, Report No. DOT HS 812 456.

Ono, K., Kanno, M. (1996). “Influences of the Physical Parameters on the Risk to Neck Injuries in Low Impact Speed Rear-End Collisions”. *Accident Analysis and Prevention*, 28(4): 493-499.

Parkin, S., Mackay, G.M., Cooper, A. (1995). "How Drivers Sit in Cars". *Accident Analysis and Prevention*, 27(6): 777-783.

Petit, P., Portier, L., Trosseille, X. (1998). "Rigid Body Model of the Hybrid III Dummy Lower Limb Including Muscle Tension Under Car Crash Conditions". *IRCOBI*, 26: 173-188.

Shaout, A., Colella, D., & Awad, S. (2011, December). "Advanced driver assistance systems-past, present and future". *In Computer Engineering Conference (ICENCO), 2011 Seventh International* (pp. 72-82). IEEE.

Svensson, M. Y., Lövsund, P., Håland, Y., & Larsson, S. (1996). "The influence of seat-back and head-restraint properties on the head-neck motion during rear-impact". *Accident Analysis & Prevention*, 28(2), 221-227.

Viano, D. C., & Gargan, M. F. (1996). "Headrest position during normal driving: implication to neck injury risk in rear crashes". *Accident Analysis & Prevention*, 28(6), 665-674.

Wiklund, K., & Larsson, H. (1998). "Saab active head restraint (SAHR)-seat design to reduce the risk of neck injuries in rear impacts" (No. 980297). *SAE Technical Paper*.

Yan, X., Zhang, Y., & Ma, L. (2015). "The influence of in-vehicle speech warning timing on drivers' collision avoidance performance at signalized intersections". *Transportation research part C: emerging technologies*, *51*, 231-242.

APPENDIX

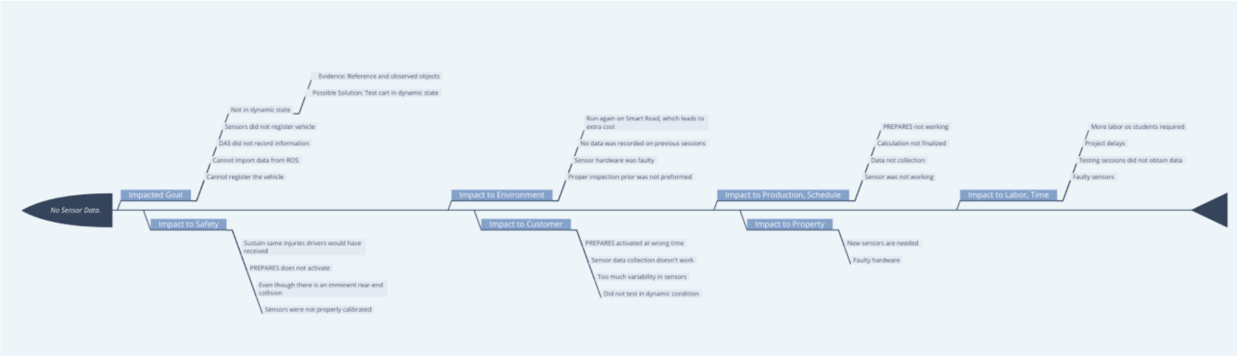

Figure 6. Fishbone Diagram

Table 2. Proposed Solutions

Possible Solutions for Consideration				**Select**
Ref.	**Possible Solution**	**Cause Controlled**	**Work Process** *(process to be improved)*	**Implement?**
A	Test the cart in a dynamic environment.	The sensors didn't work very well is because radar functions the best when both objects (the reference and observed objects) are in a dynamic state or moving. Because the cart was static, it didn't seem to pick up the other vehicle.	Cart will be moving and collecting data while the vehicle is moving around it. Option 2: the cart is moving while the vehicle is static.	yes
B	Get new radar sensor.	One of the side radar sensor is broken, it is either not working at all or the connection going to the FLEX DAS is not working. CAN data is not being recorded.	Get new radar, organize through Zac and Jake.	yes
C	Debug software.	The sensor was not recording as much data as planned due to the cart not having any velocity.	The system was spoofed so it think sit has some type of velocity. It should collect data as a better rate now.	yes
D	Get new LiDAR system.	The front data is the one that matters, so we can use this to collect some preliminary information.	We do not need to collect data via LiDAR, so this can wait to see if other solutions work.	no
E	Test in different environmental conditions (cloudy, sunny).	Can get a better idea of how the sensors interact with a wide variety of weather and within operational design domains	The super sunny condition caused the system to overheat, and super cold condition cause the radars not to function.	no
F	Run data only using front facing radar.	The front radar data is the one that matters, so we can use this to collect some preliminary information.	Collect data through the sensor that is working.	yes

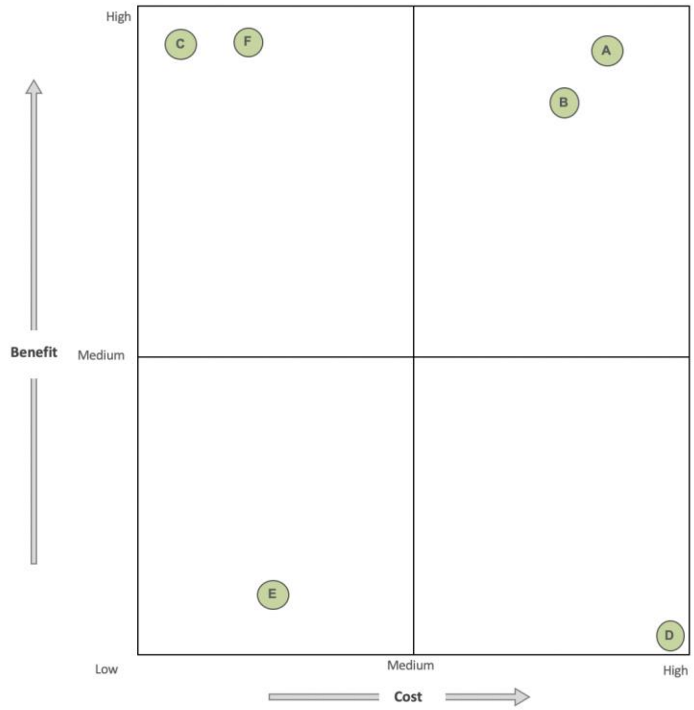

Figure 7. Solution Cost-Benefit Analysis

Implementation - Action Plan

Ref.	Possible Solution	Specific Actions *(specific actions to be taken)*	Owners *(names)*	Due Date .	Measurable *(how will we verify completion and effectiveness)*	Status
A	Test the cart in a dynamic environment.	Reserve time on the Smart Road, reserve car, go out and test.	Adam, Alli, Sammy	March 27, 2019	ROS BAG File	Pending
B	Get new radar sensor.	Connect with Jake and Zac, order new radar, implement/test new radar	Adam, Sammy, Luke	April 8, 2019	ROS BAG File, radar mounted onto cart	Pending
C	Debug software.	Work with Jake, examine FLEX DAS output, rework code.	Phil, Sammy	April 8, 2019	ROS Bag File, ROS code, FLEX DAS variable data output	Pending
D	Get new LiDAR system.	Work with Zac to order new LiDAR system, and have it implemented into cart.	Zac	April 8, 2019	New technology implementation.	Pending
E	Test in different environmental conditions (cloudy, sunny).	Create shade over the system during testing, and warmth on a cold day.	Lexi, Alli, Rick	April 8, 2019	ROS Bag File, system coming online	Pending
F	Run data only using front facing radar.	Reserve time on the Smart Road, reserve car, go out and test.	Adam, Alli, Sammy	March 27, 2019	ROS BAG File	Pending

Figure 8. Solution Implementation Plan

Table 3. Barrier Analysis Results

#	Consequence	Barrier	Why Failed	Results	Corrective Actions
1	Driver does not turn around when light and/or sound is activated.	Light brightness and salience. Sound audibility level (dB or Fq).	The sound nor the light captured the drivers attention. The driver did not understand the purpose of the alarm, and ignored it.	The driver sustains injuries they would have received if the system was not present.	Test sound and light until a localizing sound, and bright enough light is determined and verified.
2	Driver presses foot on gas when they hear the light and/or sound.	Light brightness and salience. Sound audibility level (dB or Fq).	The sound and/or light was too loud or bight and startled the driver. Another reason could be the driver did not understand the purpose of the alarm and reacted with assessing the situation.	The driver can put themselves in worse predicament if they are startled and immediately react (i.e., hit another vehicle around them, pull forward into oncoming traffic).	The brakes can be automatically applied when the interface is engaged.
3	Driver moves into a "worse" position.	The sound does not get their attention and does not localize them to the speakers position.	The driver did not understand the purpose of the alarm, and ignored it. The driver's attention was fixated somewhere else and turned around to see what was going to happen.	The driver can worsen or be susceptible to more soft-tissue injuries during the accident.	Test sound and light until a localizing sound, and bright enough light is determined and verified. Identity location of sound and light in the vehicles, and test different options.
4	Driver slams on brakes.	They should already be in the stopped position, but if they are merging on the highway they may slam on the brake.	The sound and/or light startled the driver, or did not understand the purpose of the alarm.	The driver can put themselves in worse predicament, or induce whiplash on themselves from a sudden slam on the brakes.	The brakes can be automatically applied when the interface is engaged.
5	Driver confuses PREPARES light with stimuli outside the vehicle (i.e., traffic light, buildings, etc.).	The light is not distinct enough.	The light was not distinct enough from other stimuli inside and outside of the vehicle.	The light confuses is with something else and does not react accordingly.	Test light to ensure lights do not compete with others inside the vehicle, or the brightness levels of lights drivers are expected to see outside (i.e. traffic lights, other vehicle lights).
6	Driver confuses PREPARES alarm with other sound stimuli that the vehicle produces.	The sound is not distinct enough.	The sound was not distinct enough from other stimuli inside and outside of the vehicle.	The sound confuses is with something else and does not react accordingly.	Test sound to ensure it does not match tone and frequency level to other alarms in the vehicle. Ensure light is distinct enough from general noise produced from the radio.