Effect of changing driving conditions on driver behavior towards design of a safe and efficient traffic system

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Project Objectives

The proposed research will investigate the interactions between driver characteristics and behavior with traffic conditions using a full-size driving simulator combined with human factors analysis techniques. Understanding driver behavior is critical to improving the safety of roadways, particularly in construction zones, high-traffic areas, and evacuation scenarios. Specifically, this research will address two major objectives:

1. To determine the effects of traffic patterns and traffic flow levels on driver behavior
2. To demonstrate the use of human factors analysis techniques applied to the understanding of driver behavior and performance

Project Abstract

Drivers encounter various road conditions such as merging traffics, construction zones, etc. on a daily basis. Work zone and traffic controls are mandated by the United States Department of Transportation standards. They are designed to provide a safe and efficient travel for the drivers. However, these standards can be improved further. The purpose of this study is to investigate the interactions between driver characteristics and behavior with traffic conditions. The objectives of this study are: 1) to determine the effects of traffic patterns and traffic flow levels on driver behavior, 2) to demonstrate the use of human factors analysis techniques applied to the understanding of driver behavior and performance. To achieve the objectives of this study, the LSU driving simulator will be used to gather performance data from 20 drivers to determine how individual differences and individual responses to driving conditions (perceived workload and situation awareness, etc.) shape driving behavior.

Technical Descriptions

Background

Driving is a complex task characterized by multiple factors that require the driver to process information continuously. Driving through construction work zones is particularly complex yet a common occurrence for most drivers. A typical driver passes a construction zone approximately every 100 miles

(Ullman, 2004). In construction zones, available lanes gradually decrease, closing at least one lane in the highway, which is known as the transition zone. Transition zones and lane closures create more hazards, longer delays for drivers, and a lower highway capacity (Idewu, 2009). In 2010, there were 87,606 crashes in work zones. Of the total crashes, 525 (0.6%) were fatal crashes, 26,281 (30%) were injury crashes, and 60,448 (69%) were property damage crashes (US Department of Transportation, 2012). Furthermore, the number of fatalities in work zone related crashes increased by approximately 50% between 1997 and 2003 (US Department of Transportation, 2003). Therefore, there is an increasing need to provide safe yet efficient mobility for drivers going past or near work zones.

Merging traffic in anticipation of lane closures in work zones is a major hazard to drivers, and researchers have studied ways to mitigate these hazards. Idewu (2009) developed a new merge-control design known as the "joint merge." Idewu (2009) compared the joint merge with a conventional merge configuration in terms of lane-specific volume, vehicle speeds, and vehicle lane distributions in advance of the work zone entrance and found that the joint merge configuration improved efficiency through the transition zone. Another study discussed the advantages and disadvantages of conventional forms of merge control designs: static early merge, dynamic early merge, and late merge (McCoy and Pesti, 2007). The authors proposed a new merge control referred to as dynamic late merge. Using real-time measurements of traffic conditions, the dynamic late merge operates as a conventional lane closure merging operation during periods of uncongested flow, and as the late merge during congested flow.

Individual differences also influence driver behavior. Hill and Boyle (2007) surveyed drivers' stress under various road, traffic, and weather conditions. They found differences in stress levels within demographics such as gender, age, and crash history, which suggest that driver behavior also depends on individual differences. In hopes of improving the interaction between humans and motor vehicles, Salvucci and Liu (2001) developed a model that uses observational information to predict drivers' future actions. The model uses information on the driver's current control actions (i.e. steering and acceleration actions) and the driver's visual scanning behavior to predict drivers' future actions. This model could facilitate the interaction between drivers and motor vehicles.

These examples of previous research show the need for studies on driver behavior to improve safety, various types of road design that may influence behavior, and individual differences that influence driver behavior. This research serves as the basis for the current proposal.

Experimental Tasks

The major tasks in the proposed research includes the following steps:

Task 1: Modify driving simulation to model a highway construction zone

The driver will navigate through a simulated construction zone. The factors tested in this construction zone will be lane merges and traffic congestion level. There will be two types of lane merges: conventional and joint (two-sided taper), and two levels of congestion: high and low.

Task 2: Conduct a driving simulation experiment

Using the simulation developed in Task 1, twenty students at LSU will be recruited to participate in an experiment to test their behavior and responses to various driving conditions. Each participant will experience all combinations of merge type (conventional and joint) and traffic level (high and low). Driver performance will be measured with standard data from the driving simulator such as lane deviation, speed, braking patterns, and success in completing the driving tasks. Behavior of the drivers will be recorded using digital cameras and possibly an eye tracking device. Performance-shaping variables including perceived workload and situation awareness will be recorded to determine if there is any correlation between these and driving performance. Finally, individual differences in driving style, personality type (A or B), gender, age, and driving experience will be recorded to further analyze the performance data.

Participants' perceived workload will be measured in several dimensions (mental workload, physical workload, temporal workload, frustration, performance, and effort) using the NASA-TLX (Task Load Index). Participants mark a continuous scale from low to high on each dimension at the end of the experiment to reflect their workload.

Situation awareness (SA) measures the level of awareness a person has of his/her environment at three levels: perception, comprehension, and projection. SA has been correlated with performance in related fields such as aviation and maritime navigation. Using SAGAT (Situation Awareness Global Assessment Technique), participants are interrupted for short periods of time during the simulation to answer questions on SA at all three levels of awareness.

Type A or Type B tendencies are a popular personality type description. In addition to describing personality, these tendencies have been linked with risk for heart disease and increased muscle activation. It is hypothesized that Type A personalities will be more aggressive drivers. This personality characteristic will be measured using the 20-item Jenkins student activity survey.

Task 3: Analyze human factors data

Statistical analysis will include descriptive statistics of performance, ANCOVA to determine differences in driving conditions on performance when individual differences are considered, and correlation analysis to determine relationships between performance, performance-shaping metrics, and individual differences. The end product of this analysis will be a description of how individual differences and individual responses to driving conditions (perceived workload and situation awareness) shape driving behavior.

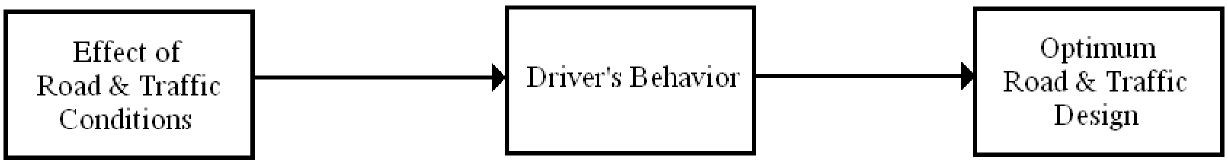
Resources

The proposed experiment will be conducted using the full-size driving simulator housed in the LSU driving simulator lab in the Department of Civil and Environmental Engineering. All analysis will take place using the accompanying software and statistical packages such as SAS and SPSS.

Two graduate students in the industrial engineering program will be responsible for modifying the current simulation, running the experiment, and conducting statistical analysis. The investigators will oversee the project, with Drs. Aghazadeh and Ikuma providing human factors knowledge, and Dr. Ishak providing knowledge on traffic and road design and in operating the driving simulator.

Potential Benefits of the project

The purpose of this study is to contribute to the development of new techniques to improve the ability of transportation system to safety and efficiently handle the traffic demand. The project's current and future aim is summarized in the following model.



By measuring the behavior of a driver, we will determine how a driver responds to varying road and traffic conditions. Once the driver behavior is known and documented, the data can be used to modify road and traffic conditions in order to create conditions under which the driver will have the optimum driving behavior. Ultimately the results of this study and subsequent studies will enable the designers and planners to move towards an optimum traffic control. Reduced congestions, increased speed and capacity, and satisfied drivers will facilitate emergency evacuations. The result of this study will be used to solicit funds from agencies such DOTD and NSF.

Contribution to the Field of Evacuation or Transportation Resilience

The current proposal investigates a critical component of transportation systems, driver safety. By applying knowledge of driver behavior from a human factors perspective, our research will develop a better understanding of how individual differences and driver behavior can influence driver safety, and will improve traffic flow under conditions such as construction zones and evacuation plans.

Deliverables

At culmination of the project a comprehensive report containing the gathered data, statistical analysis, and the research findings, along with conference papers and journal papers, will be prepared. The end product of this analysis will be a description of how individual differences and individual responses to driving conditions (perceived workload and situation awareness) shape driving behavior.

Investigators Biographies and Recent Work

Dr. Fereydoun Aghazadeh has over 25 years of teaching and research experience in safety and human factors engineering. He has authored over 170 publications that include refereed journal articles and conference proceedings, books and book chapters, technical reports, and presented many papers at national and international conferences. His extensive HF research experience involves laboratory and field research. An example of the former is a research which resulted in the following publication and used a driving simulator and an eye tracking equipment.

> "Effect of driving experience on visual behavior and driving performance under different driving conditions." J. of Cognition Technology & Work

An example of the later is the following LTRC project:

> "Analysis of User Waiting Costs for Construction Projects on Louisiana's Interstate Highway System."

He was also a Ph.D. committee member for Dr. Wakeel Idewu, who completed the following dissertation at LSU:

> "Development and Operational Analysis of Highway Alternating Merge Transition Zones"
> This dissertation investigated:

- Transition zone design
- work zone traffic control plan
- joint merge
- alternating merge

He is Professor of Construction Management and Industrial Engineering Department and Georgia Gulf Distinguished Professor of Engineering at Louisiana State University. His teaching and research interests include applied ergonomics, biomechanics, safety engineering, anthropometry, and work/workplace design. After joining the IE department at Louisiana State University, he started a Human Factors and Safety Engineering program. The Ergonomics/Human Factors program at LSU is the only one in the state of Louisiana. For the past 25 years, he has served industrial and educational organizations as a consultant and has conducted research in various areas of Human Factors and Ergonomics. He has served as a Summer Faculty Fellow at NASA's Johnson Space Center in Houston. He has authored over 170 publications that include refereed journal articles and conference proceedings, books and book chapters, technical reports, and presented many papers at national and international conferences in US, Canada, China, England, France, Korea, Mexico, and Netherlands. He is a founding member of the International Society for Occupational Ergonomics and Safety and a member of various professional organizations including the Human Factors and Ergonomics Society, American Industrial Hygiene Association, and IIE. He has served these organizations as president, treasurer, conference chair, technical committee chair, etc. He has had editorial or review responsibilities for a number of peer-reviewed journals, including the International Journal of Industrial Engineering, Occupational Ergonomics, and the International Journal of Industrial Ergonomics. He is a registered professional engineer and a registered member of the Ergonomics Society. He is a fellow of the Ergonomics Society.

Dr. Laura H. Ikuma specializes in the effects of psychosocial factors on work-related musculoskeletal disorder risk and has broader research interests in occupational ergonomics, safety, and the links between productivity, safety, and ergonomics across various industries. She will bring her experience in combining multiple risk factor measurements for physical, psychosocial, and performance aspects of work activities to the current project. She also has experience conducting laboratory experiments using virtual environments and has advised students on driver distraction projects. Dr. Ikuma is an Assistant Professor in the Department of Construction Management and Industrial Engineering (CMIE) at Louisiana State University (LSU). She received her PhD (2007) and MS (2004) degrees from Virginia Tech in Industrial and Systems Engineering and her BS (2002) from North Carolina State University in Industrial Engineering. She currently has 14 refereed journal publications and 18 refereed conference proceedings.

Dr. Ishak has research experience in several and diversified topics in transportation engineering including traffic simulation, data collection technologies, traffic operations, traffic safety, Intelligent Transportation Systems applications, and artificial intelligence. Some related previous and current research projects are:

- S. Ishak (PI), "A Driving Simulator to Study Human Behavior and Improve Traffic Operation and Safety in Louisiana," LA Board of Regents, $182,060 (2010-2011).
- S. Ishak (PI), "Resilient Transportation: An Integrated Corridor Management Approach," US Department of Transportation, $37,023 (2009-2010).
- S. Ishak (PI) and B. Wolshon, "Establishing an Intelligent Transportation Systems (ITS) Lab at LTRC," Louisiana Department of Transportation and Development / Louisiana Transportation Research Center, $49,994 (2007-2008).
- B. Wolshon (PI) and S. Ishak (Co-PI), "Safety and Operational Assessment of Unconventional Lane Merges in Freeway Work Zones", Louisiana Department of Transportation and Development / Louisiana Transportation Research Center, $140,000 (2007-2000).
- S.S. Ishak (PI), "The Urban Data Warehousing/Data Mining (Dw/Dm) Component For ITS: Statewide Planning Phase," Louisiana Transportation Research Center through Tulane University (2003-2005).
- S.S. Ishak (PI), "Exploring New Traffic Characteristics and Performance Measures Using Feature Extraction and Texture Characterization of Spatiotemporal Traffic Contour Maps," National Science

Milestones

The following milestones will be used to gauge progress towards the stated research objectives over a one-year period from June 1, 2012 to May 31, 2013.

Milestones and expected time required

	Month (June 1, 2012 – May 31, 2013)											
Milestone	6	7	9	10	11	12	1	2	3	4	5	6
1. Literature review	X	X										
2. Programming of all experimental conditions within the driving simulation and develop experimental protocol	X	X	X	X								
3. Recruit participants and obtain IRB approval for the experiment			X	X	X							
4. Conduct experiment and complete data collection						X	X	X				
5. Analyze experiment data and provide results and conclusions from the research						X	X	X	X	X		
6. Prepare final report and proposal for continued funding, and papers for publication and presentation										X	X	X

Budget

The research budget includes $42,000 requested from the sponsors and an additional $42,711.00 in matching funds provided by LSU. Funds are requested for faculty salary and 2 graduate students in industrial engineering for 12 months. Required university fringe benefits and overhead are included in these totals.