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Project Title:
The Effects of Autonomous Vehicles on Safety and Safety Culture in Freight Operations

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Research Needs:
Major manufacturers and developers are working hard to develop autonomous and self-driving vehicles. Companies like Waymo, Uber, Tesla, Volvo and Daimler Trucks are working to bring self-driving trucks to market.[1]

Automation will not make drivers obsolete however, but they won't make truckers obsolete due to the fact that truck drivers must do a number of managerial tasks with the freight they are transporting. Truck drivers will need to focus on tasks that cannot be performed with current technology. "You're going to need that driver or whomever to physically check to make sure that the goods are not damaged in any way as they're being loaded," said Cathy Morrow Roberson, head analyst for consulting firm Logistics Trends and Insights.[2]

In addition to autonomous vehicles on public roadways, self-driving tractor trailers, cranes and lifts are currently in use to stack containers and deliver them to waiting trucks and soon onto railcars. TraPac, a Long Beach container port facility, uses autonomous technology to move freight containers. TraPac's equipment reduces the time to load and unload ships further enhancing productivity and profitability.[3] In addition, the use of self-driving vehicles may also contribute to reduced emissions. The state of California has provided funds for the purchase of battery-powered tractor-trailers at a new automated facility in the Long Beach Container Terminalwhich will use electric, self-driving cranes and carriers guided by transponders buried in the cement on the dock. The new equipment will double the volume of containers the terminal handles while cutting emissions in half, according to Art Wong, spokesman for the Port of Long Beach.[4]

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[1] https://www.trucks.com/2017/06/14/self-driving-trucks-need-drivers/
[2] Ibid.
[3] http://www.seattletimes.com/business/self-driving-robots-are-the-new-longshoremen-on-la-waterfront/
[4] Ibid.

At Trapac a few dozen people monitor in control rooms. On the wharf itself, TraPac uses people only to run the cranes that unload ships and to drop containers the last few feet onto waiting trucks and trains. The question of how the use of autonomous vehicles will affect the workforce remains and open question. There are many predictions that AV will reduce the number of accidents and incidents on highways and roadways. However, more intense and concentrated operations may require additional training and monitoring to ensure that there is a safe environment.

Sam Loesche, a Teamsters lobbyist, has said that, "We have not seen a situation where any responsible operator would agree that there's a role for this technology without an operator in the cab. Our view is [that] the best piece of safety technology is the driver."[5] Joan Claybrook, former head of the National Highway Traffic Safety Administration, says it could take 10, 20, even 30 years of tinkering with and improving self-driving technology until it is truly safer than human drivers.[6] The International Brotherhood of Teamsters asserts that "self-driving trucks will continue to need a driver to help out in case of emergencies, to handle paperwork, to assure the safety of the cargo, to pull a truck into a warehouse."[7]

Technologically advanced automotive systems may enhance safety in comparison to human-only-operated vehicles. For self-driving vehicles to succeed at maximizing safety, they will need extensive testing and research. It is generally agreed that situational awareness, or the full understanding and appreciation of the surrounding environment, is critical for safety. However, collection and analysis of situational awareness data that influences the prevention of transportation related accidents is a significant hurdle for the automotive industry and at this point a barrier to developing vehicles that are reliable, safe, and operable.[8] Partial autonomy may be the name of the game in the near future as operators are used to augment the safety technology of experimental vehicles.

In the freight environment, the "longest continuous journey by a driverless and autonomous" vehicle was conducted on Oct 20, 2016 when a load of Budweiser beer was transported 132 miles from ft. Collins to Colorado Springs.[9] While there was a person in the vehicle, he was monitoring the trip from the back seat and never took the wheel. He did however, drive it onto the interstate and off the interstate into the loading area.

The "Self Drive Act" was unanimously approved by the House Energy and Commerce Committee in July, before Congress left for August recess, and passed the full House on a voice vote.[10] According to one estimate, self-driving cars could reduce traffic fatalities by up to 90 percent. However, when Joshua Brown's Tesla collided with a tractor-trailer in 2016 at more than 70 miles per hour, the fatality and accident became the world's first known car crash

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[5] http://prospect.org/article/driverless-future
[6] Ibid.
[7] Ibid.
[8] https://commonwealthmagazine.org/transportation/situational-awareness-key-to-safe-self-driving-cars/
[9] http://www.denverpost.com/2017/06/29/self-driving-beer-truck-world-record/
[10] http://thehill.com/policy/technology/349418-house-passes-driverless-car-legislation

involving a partially autonomous vehicle. Results of the NTSB analysis of the available data indicated prior to the collision, Brown was audibly warned six times and visually warned seven times, to keep his hands on the steering wheel. The recorder data reviewed by NTSB and Tesla indicated that Brown had his hands off the wheel for 90 percent of his final drive, according to Tesla vehicle data reviewed by the National Transportation Safety Board.[11] Other data suggest that Brown had overridden the controls and set the cruise control for 74 mph (nine MPH above the speed limit) less than two minutes before the crash.[12]

The Prius also has dynamic radar cruise control that, maintains a specific speed on the highway but applies the brakes when it senses the car in front slowing down or stopping. However, the Prius owner's manual warns, "There is a limit to the degree of recognition accuracy and control performance that this system can provide. Do not overly rely on this system. The driver is always responsible for paying attention to the vehicle's surroundings and driving safely."[13] Thus, until fully autonomous vehicles are perfected, research needs to be conducted which will inform manufactures, policy makers and drivers of the risks and countermeasures that will need to be managed and used to protect the human driver, whose software will never be perfected.[14]

A recent report reviewed a number of studies from NHTSA and aviation relative to issues with attention and vigilance with respect to in-vehicle safety technology. For example research by Strayer et al.[15] found interacting with voice-controlled navigation systems can be just as distracting as manually operated systems.[16] Also, many psychological studies show people have trouble focusing their attention when there is little or nothing to attend to. In such situations, they tend to reduce their active involvement and simply obey the automation. There is already ample evidence drivers disengage from the navigation task when the automation is programmed to lead the way.[17] Casner and Schooler[18] found well-trained airline pilots report "mind wandering," when an advanced navigation system is being used and the flight is routine and normal. Palmer et al.[19] described many cases in which pilots missed an assigned altitude because the alerter failed to sound. Thus, it appears that it is easy for drivers to be distracted and less vigilant for prolonged periods when they rely on technology to alert them to trouble. Dufour[20] showed relieving drivers of even one aspect of the driving task results in reports of increased driver drowsiness and reduced vigilance when driving on open stretches of road. But the effects do not stop there. Dufour also showed drivers take more time to respond to sudden events when they use cruise control.

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[11] https://www.washingtonpost.com/news/the-switch/wp/2017/06/20/the-driver-who-died-in-a-tesla-crash-using-autopilot-ignored-7-safety-warnings/?utm_term=.ae711f042cb8
[12] Ibid.
[13] http://www.mercurynews.com/2017/06/21/automatic-safety-features-in-cars-are-no-substitute-for-driver-vigilance/
[14] Ibid.
[15] https://cacm.acm.org/magazines/2016/5/201592-the-challenges-of-partially-automated-driving/fulltext#R36
[16] https://cacm.acm.org/magazines/2016/5/201592-the-challenges-of-partially-automated-driving/fulltext
[17] https://cacm.acm.org/magazines/2016/5/201592-the-challenges-of-partially-automated-driving/fulltext#R26
[18] https://cacm.acm.org/magazines/2016/5/201592-the-challenges-of-partially-automated-driving/fulltext#R10
[19] https://cacm.acm.org/magazines/2016/5/201592-the-challenges-of-partially-automated-driving/fulltext#R29
[20] https://cacm.acm.org/magazines/2016/5/201592-the-challenges-of-partially-automated-driving/fulltext#R15

The results clearly point to the conclusion that if you take drivers out of the role of active control, it is difficult to get them back in when they are needed. The inference that must be that drivers and operators of semi-autonomous vehicles will be required to pay full attention to the driving situation, even if they are not required to actually do anything. Most critical is that they may need to take control of their vehicle in unexpected circumstances, usually fairly quickly. Experience with pilots suggests that this will not go smoothly for everyday drivers. Typical reaction times, where milliseconds might mean the difference between life and death, may not be sufficient. Drivers will likely expect their vehicles safety systems to prevent accidents and will probably expect automated warnings to alert them when their attention or action is needed.[21]

In the freight environment, a similar set of circumstances may arise where reliance on safety equipment and technology can lead to a lack of vigilance. Given that some of these settings may not be on the open road adoption of partially automated equipment may take place at a more rapid pace in freight yards and warehouses. Accordingly, the risk of safety lapses in such an environment are greater than a non-automated or fully automated environment. Consequently, the present research seeks to address the issues of how the introduction and adoption of technology into an operating environment might affect safety attitudes, safety practices, and accidents and incidents in the immediate environment.

One of the key factors influencing the number of accidents that occur in the workplace, or in an autonomous or semi-autonomous work environment, is safety culture. As noted in our previous work the FRA has expressed interest in studying safety culture in railroad operations and recently FRA and BNSF engaged in a joint effort to review the BNSF Safety Culture (FRA, April, 2015).[22] Also, FRA Administrator, Sarah Feinberg, noted when discussing a recent incident involving Metro-North that, “safety culture, preventing accidents before they happen and increasing worker safety,” was important. The FRA also stated that “Multiple studies have confirmed what many have intuitively known all along” that safety culture plays a key role in accident prevention. However, visible progress towards established goals is a more effective motivator than money or personal recognition for the average worker in a world-class operation. Moving towards achievement metrics and away from failure metrics becomes increasingly vital. (FRA, August 2011)[23] Accordingly, the present research is designed to continue the development of a viable measure of safety culture by continuing the validation process with a large commuter rail transportation organization.

Recently, Sherry & Colarossi (2016)[24] released a study that initiated the development of a tool to measure of safety culture. The instrument was normed on a large sample of employees of a large public transportation agency (N=1909) participants were obtained. One-way between groups analysis of variance (ANOVA), and post hoc tests provided initial evidence of the validity and reliability of the Safety Culture Scale as a measure for the transportation industry in that the scale

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[21] Casner,S., Hutchins,E., & Norman, D. (2017). The Challenges of Partially Automated Driving. Communications of the ACM, Vol. 59 No. 5, Pages 70-77, 10.1145/2830565
[22] http://www.fra.dot.gov/eLib/details/L16311
[23] https://proactsafety.com/articles/establishing-a-sustainble-safety-culture
[24] http://www.ncit.msstate.edu/PDF/reports_76_2012_22_Sherry_&_Colarossi_Safety_Culture_Measure_Report_NCITEC.pdf

significantly differentiated ($p<.05$) between persons who had been involved in accidents and safety violations thus demonstrating the relationship between safety culture and accident rates. (See Figure 1.) In addition, a follow-up study with a large regional rail transportation company demonstrated significant differences in safety culture and attitudes between key departments in the organization. (See Figure 2.)

A normative instrument designed and validated on railroad properties is needed because of the vastly different environment and set of operating practices, corporate culture, historical traditions, and unique set of working conditions. Much of the published material on safety culture has to do with nursing, hospital practices[25] and oil and gas operations.

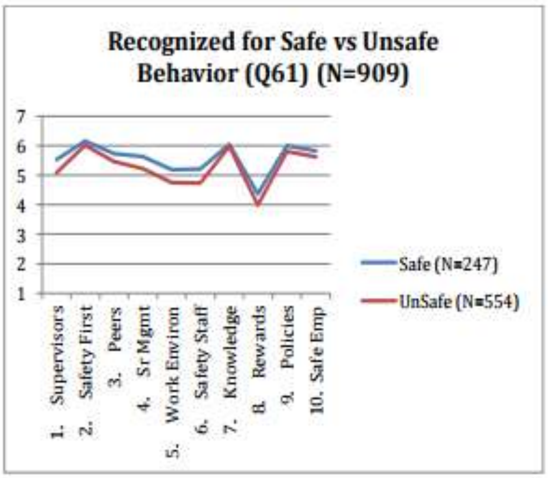

Figure 1.

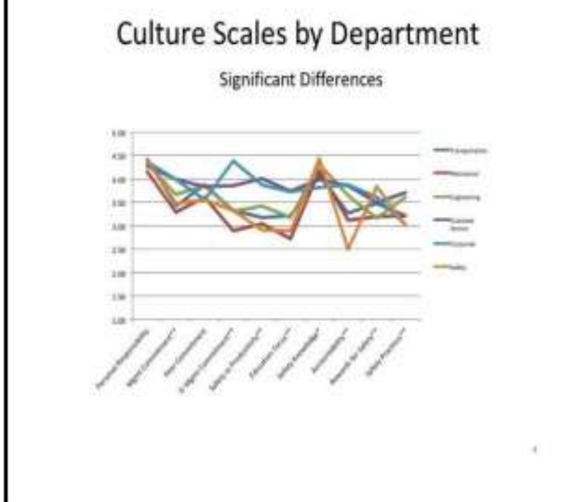

Figure 2.

A review of the literature of safety culture in the trucking industry by the Transportation Research Board (2007)[26] identified several key aspects of performance that were related to safety culture including:

- Inattention to tasks and responsibilities.
- Lack of motivation to perform well.
- Lack of awareness

These factors might be especially affected by the introduction of autonomous or semi-autonomous vehicles into an operational environment. As such, the safety culture, that many companies go to great lengths to develop and maintain, could be negatively impacted and require additional efforts to address. The utilization of a standard measure of safety culture to assess the impact of the introduction and utilization of autonomous and semi-autonomous vehicles into an

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[25] Vogus, T.J., & Sutcliffe, K.M. (2007). The safety organizing scale: development and validation of a behavioral measure of safety culture in hospital nursing units. *Medical Care*. 2007;45:46–54.
[26] https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Commercial_Truck_and_Bus_Safety-The_Role_of_Safety_Culture.pdf

operational freight environment is needed. By assessing safety culture, and accident rates the comparison of pre-post interventions as well as the normative comparison of organizations to each other, we can monitor and evaluate the impact of autonomous or semi-autonomous vehicles into an operational environment. In addition, such measurements could also aid in the identification of areas within an organization, such as departments, relationship between management and labor, training programs and other areas that are in need of improvement relative to establishing a strong safety culture.

Thus, the proposed study will monitor and evaluate the impact of autonomous or semiautonomous vehicles on safety and safety culture in an operational environment.

Research Objectives:

1. Obtain buy-in and collaboration from private industry on a key investigation into the role of autonomous vehicles and safety culture from industry partners.
2. Review of current literature on autonomous vehicles and safety culture
3. Brief stakeholders in organization on the importance of safety culture
4. Assessment of organization on safety culture through interviews, online, and paper and pencil administration.
5. Gather historical data on occurrence of accidents and incidents in the operational environment.
6. Perform data analysis to determine relationship between the presence of autonomous vehicles and the impact on safety culture and safety performance.
7. Conduct feedback presentations to stakeholders and community leaders in a public workshop.
8. Prepare draft of report and development of recommendations.
9. Disseminate reports and post on web site.
10. Deliver peer reviewed presentations at conferences and workshops on autonomous vehicles, safety culture and rail safety.

After obtaining buy in and commitment from industry partners and reviewing the literature on safety performance and safety culture both present time and historical data will be gathered. Measures of safety culture, historical records of safety performance and focus groups will be used to assess current attitudinal and work practices regarding safety. Statistical analyses will be performed to assess the relationship between introduction and use of autonomous vehicles and safety performance and safety culture in the freight transport environment. Subsequently, meetings with stakeholders, a conference with local community industry representatives, and dissemination of results through media, conference presentations and papers will be conducted.

Research Methods:

The project will primarily utilize survey and interview methodology to gather data which will use statistical techniques to review and evaluative the data.

Observational Data – A team of investigators will conduct onsite inspections and observations of work behavior and conditions of the sample freight operation during a one week period of observation. The inspectors will be looking for examples of safe and unsafe worker behavior. A checklist of typical work behaviors will be prepared prior to the onsite visit.

Historical Data – Reports on the accident incident rate of the study organization will be examined. Data will be gathered and compared to scores obtained on the survey instrument (SCS). Both analysis of variance and regression analysis will be sued to obtain estimates of the relationship between and the impact of safety culture variables on the occurrence of accidents and incidents. Since this is a correlational field study only associational relationships will be possible to determine.

Questionnaire Data – The data on safety culture will be obtained through the administration of Safety Culture Scale (SCS) (Sherry & Colarossi, 2016). The SCS was developed using a large sample of employees from a large public transportation agency (N=1909). Confirmatory factor analysis (CFA) compared the fit of likely models. One-way between groups analysis of variance, and post hoc tests provided initial evidence of the validity and reliability of the SCS as a measure for the transportation industry in that the scale significantly differentiated ($p<.05$) between persons who had been involved in more accidents and safety violations thus demonstrating the relationship between safety culture and accident rates. Implications of these findings are that the safety culture survey could be used to assess safety awareness and safety culture of trucking or transport companies, small communities, and other organizations involved in transport. By carefully monitoring scores on the SCS efforts could be made in various communities and organizations to improve attitudes towards safety and ultimately to reduce accidents and improve road safety.

Focus Group Data – The research team will conduct onsite focus groups and interviews with key personnel from the freight operation during a one week period of observation. The inspectors will be looking for examples of safe and unsafe worker behavior. A checklist of questions will be prepared prior to the onsite visit.

Expected Outcomes:
The research will identify the relationship between the introduction and utilization of autonomous and semi-autonomous vehicles, the safety culture and the accident incident history of the sample organization. The project will also contribute to the identification of statistical patterns and degrees of association between those patterns. Results of the study will contribute to workforce development efforts by disseminating knowledge about the impact of autonomous vehicles and autonomous technologies on the impact of safety performance and safety culture in an operational freight environment.

Relevance to Strategic Goals:

- Safety
- Economic Competitiveness

This project will contribute to the safety of employees and personnel of the freight and logistics industry by assessing safety in that industry. These measurements have been used and normative data from a number of railroads has been gathered to be able to successfully calibrate and compare between organizations. In addition, it will enhance and contribute to the safety of the rail industry and the public at large. The project will enhance the existing federal effort by contributing to safety, economic competitiveness and efficiency and developing the work force in the transportation system in the US.

Educational Benefits:
Several graduate students will assist with the project thereby contributing to the development and education of graduate students who will later be employed in the industry. These students will gain experience in the data collection techniques commonly used in the transportation industry. In addition, they will gain an understanding of the theory and best practices associated with safety and safety culture.

Tech Transfer:
There will be three mediums for technology transfer. First, small briefing meetings with stakeholders will be held to discuss the result so the study will be conducted. This will include members of the organization (eg. Trapc) as well as employees, labor, management and other officiations associated with the local site. Discussions regarding the implications of the findings for the local operations and community will be discussed.

Second, papers and reports will be placed on our web site. These will be avaialb to interested parties and will consist of the findings and recommendations of the study. A one page summary of the results will be prepared and disseminated using this medium.

Finally, A regional conference on the safety culture and autonomous vehicles and safety technology will also be planned and conducted. This will most likely be held in Denver, Colorado and consist of a one-day workshop to present findings as well hear from other local and regional experts on the impact of this technology.

Work Plan:
1. Literature Review
2. Data Collection
3. Data Analysis
4. Report Preparation
5. Dissemination of Results

Achieving the overarching goal of this project requires the completion of several different tasks. Since the project will be built upon the previous work and studies we anticipate that the results will be a significant contribution to the existing literature. In addition, it will not be necessary to invest time and effort into developing the assessment tools thereby shorten the overall project. Permission from industry participating organizations will be needed to implement these data gathering efforts.

Task 1 – Literature Review
Various sources will be consulted to identify relevant psychological, operational, and experimental studies and papers. These papers will be reviewed for their identification of relevant work practices relevant to the measurement and development of safety culture and the associated risk of accident of injury.

Task 2 – Data Collection
Data collection in the various methods and techniques outlined above (survey, observation, and historical).

Task 3 – Data Analysis
Data will be analyzed to assess the relationship between autonomous vehicle usage, the various measures, observed work practices and the accidents and injuries associated with indicators of safety culture.

Task 4 – Report Preparation
A draft report will be produced describing the results of the correlations between the use of autonomous vehicles and the various measures of safety culture. The results will first be discussed with stakeholders and then disseminated at regional and national meetings where members attend and posted on relevant web sites.

Task 5 – Dissemination of Results
A series of meeting with stakeholders and interested parties will be held following the completion of the draft report. The draft report will be shared with stakeholders and relevant feedback will be obtained and integrated into the report. In addition, The results will be presented at national conferences and disseminated in the form of scholarly papers which will be published in reputable journals. Finally, a regional conference on the topic will be conducted and additional outside experts invited to attend and comment on the study, its findings and implications for national implementation.

Project Cost:

Total Project Costs:	$359,884
MPC Funds Requested:	$179,942
Matching Funds:	$179,942
Source of Matching Funds:	TraPac, ASLRRA, Univ of Denver, CMA-CGM

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