Optimization of VDOT Safety Service Patrols to Improve VDOT Response to Incidents

(Technical Paper)

American Policymaker Safety, Privacy, and Security Preparations for Autonomous Vehicles

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

Colin M. Hood
Spring, 2020

Technical Project Team Members
Elizabeth Campbell
Emma Chamberlayne
Julie Gawrylowicz
Allison Hudak
Matthew Orlowsky
Emilio Rivero
Michael Porter, Ph.D.

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

INTRODUCTION

The National Highway Traffic Safety Administration conducted a study in 2008 to understand the primary cause of modern roadway accidents, and it was discovered that 93 percent of all accidents on roadways were attributed to a variation of driver error (NHTSA, 2008). Recent studies have found similar results, and a reported 36,560 deaths due to roadway accidents occurred in 2018 (National Center for Statistics and Analysis, 2019). While roadway accidents have dropped since 2018, death due to unintentional injury remains the third highest cause of death in the United States, claiming 6% of total fatalities in 2017 (Heron, 2019). The implementation of Autonomous Vehicle technology has been one of the leading factors in combatting human error on roadways and improving driver safety. The high priority issue of driver safety has inspired experts in the fields of control theory, motion planning, and risk mitigation to prepare a solution of fully autonomous road networks—which could be seen as early as the year 2040 (Wang et al., 2019). While researchers and scientists prepare a solution to improving driver safety, American Policymakers will be the determining factor behind the implementation of modern technology into society in order to account for the interests of public safety, technological development, and driver privacy.

The Department of Transportation has identified avenues of interest involving Autonomous Vehicle technologies with regards to addressing liability concerns and maintaining the human factor failsafe; however, policymakers are more focused on servicing the immediate issues along roadways, like ensuring continuous traffic flow (Shuster et al., 2019). The Virginia Department of Transportation has established the Safety Service Patrol (SSP) program to maintain the continual flow of traffic along Virginia roadways and aid in the prevention of driver error and accident mitigation. The SSP program consists of a fleet of designated service vehicles that patrol high traffic density Virginia roadways to clear lane obstructions, manage traffic, and aid motorists in distress. The technical topic of this capstone uses statistical analysis and geographic information systems to optimize the routes of these SSP vehicles to improve response times to incidents improve the rate of roadway obstruction clearance.

TECHNICAL TOPIC

The Virginia Department of Transportation manages all aspects of transport throughout the state, from roadways to bridges, maintenance to new development. The department receives funding from the state and works with other agencies to maintain safety across the state. VDOT funded Safety Service Patrol Vehicles to assist in traffic control and general safety assistance. The purpose of the SSP program is "to promote the efficient and effective flow of traffic through effective incident detection, verification, and notification to appropriate agencies to initiate rapid clearance of an incident," (Edara, 2006). SSP patrols in areas with high motorist density and fast-paced traffic patterns put greater emphasis on the benefits associated with reduced travel delays and number of secondary incidents. Patrols in rural regions direct greater efforts towards improved safety for motorists in distress while maintaining a high standard of upholding safety for incident responders and improved transportation system security. While geographic differences lead to unique priorities of their mission set, SSP programs are outfitted to conduct a core set of five functions, defined as: detection/verification and response, scene management, traffic management, incident clearance, and motorist information (Edara, 2006).

Today, the VDOT SSP program is comprised of five operating regions, with a fleet of 168 vehicles covering approximately 846 miles of major interstates, including I-95, I-64, I-81, and I-66 (Virginia, 2019). A patrol is tasked with servicing a designated range of roadway for the duration of the 8-hour shift period, and will receive and respond to reported incidents via the traffic operations center. The SSP vehicle program faces inefficiencies and constraints in their route selection and scheduling process. With their core function to assist traffic control and help travelers navigate the scene safely, VDOT measures the performance of their program using metrics of how quickly they can arrive on the scene and how quickly they can clear the scene. The team must use these metrics to help create an optimal schedule wherein response time to a scene and roadway clearance is minimized while the number of incidents responding to is maximized (Porter, 2019). This new schedule will help VDOT use their resources efficiently and keep Virginia moving.

The team will approach the route optimization in two phases of analysis. In the first phase, the team will evaluate the current SSP routes based on Response. The first phase of route optimization will include an investigation on where the accidents are primarily occurring and their detection sources. The comparative analysis of current and previous routes will help foster new insights surrounding route optimization. Given Response Time is in control of VDOT personnel, the team will use this metric to measure performance of the routes. Additionally, one of the core goals of the SSP program is to help minimize incident duration through traffic management (Truitt, 2019). Therefore, the team will also use Roadway Clearance Time as a secondary metric. In cases of more severe incidents, VDOT personnel largely serve to assist emergency responders and state police with traffic management (McCann, 2019).

In the second phase of analysis, the team will work towards an SSP schedule with one driver on each route, will account for gaps in current routes, and recommend routes in order to minimize the median response time. The new schedule will identify areas of high Response Times and locations with a high volume of incidents, both indicators of greater SSP demand. The recommended schedule will break interstate 95 into patrol routes that minimize median Response

Time of an SSP to an incident. Patrol routes will be described by mile markers, and time of operation will specify the hours of the day in which one SSP vehicle will be on patrol. The deliverable for the project will be an updated route patrol schedule that will target areas of high incident probability.

STS TOPIC

Societal concerns will outline the construction of Autonomous Vehicle technology and its implementation on modern roadways, and American policymakers will be the determining factor behind its development. American policymakers are addressing public safety, technology capabilities, and privacy concerns when preparing for a future with Autonomous Vehicles and will rely heavily on Engineers and public opinion as their primary stakeholders in the policy change. Engineers will provide policymakers clear synopses of how well Autonomous Vehicle technology is performing in simulations. For instance, through the use of Monte Carlo simulation, a computational algorithm that uses repeated random sampling to generate a broad array of potential outputs, has provided engineers with the ability to perform safety assessments that verified the feasibility of real-time trajectories in safety-oriented scenarios with fully Autonomous Vehicles (Wang Y., et al., 2019). Dr. Yijing Wang, Ph.D., and her research team have built dynamic models to ensure the safe passage of Autonomous Vehicles in moving traffic schemes, even accounting for the dangers of automatic lane switching; this technology addresses sensor perception, trajectory planning, and predictive control to optimize driver safety.

Engineers are also focused on how Autonomous Vehicles will respond to constantly changing obstructions along predicted paths. The vehicle having the ability to verify long-term path trajectory and reform trajectories based on the detection of potential collisions will have to exist without input from driver-interaction, and researchers have created algorithms to receive and anticipate roadway obstructions and alter course (Gruber, Althoff, 2018). The ability to interrupt a running path due to the reception of new information from sensors is essential to creating a self-reliant vehicle. With multiple moving parts within the environment of operation, there is a level of uncertainty that can be mitigated but not eliminated from the system. Dr. Hong Wang and her research team developed algorithms for the vehicle to identify the path of least resistance (least potential damage) and quickly reform its trajectory path to minimize damage in the case of unavoidable collision (Wang H., et al., 2019). This concept correlates to the STS framework of risk analysis, developed by Ulrich Beck. Beck identifies risk mitigation in society as, "a systematic way of dealing with hazards and insecurities induced and introduced by modernization itself," similar to the techniques Wang uses to address hazards caused by modern technology problems (Beck, 1992).

The development of Autonomous Vehicle predictive technology is essential to safe operation of vehicles on roadways, and the protection of these systems from cyber-physical attacks is another topic of interest among engineers. Algorithms designed to detect outside influence and secure the safety of its own system must be reinforced with robust deep learning methods to ensure safety of system control (Ferdowsi et al., 2018). Cyber-physical attacks on autonomous vehicles is a concern, not only for the engineers designing the technology, but also for policymakers responsible for protecting the public from terrorist or international threats.

Within the transcript of a hearing on autonomous vehicles to the committee on transportation and infrastructure, Congress identified various levels of Autonomous Vehicle technology according to the presence of non-manual technology within a vehicle's system. Cars with no computer input, no rear-view cameras or steering assists are considered zero-entry vehicles, whereas fully automated vehicles are at the top of the hierarchy (Shuster et al., 2019).

The identification of Autonomous Vehicles within today's roadways is essential to developing policy that allows for modern, technology-based vehicles and nonautonomous vehicles to share roadway infrastructure.

The mix of autonomous and nonautonomous vehicles must also take into account pedestrians within crosswalks. Public perception on the reliability of autonomous vehicles will determine the extent to which autonomous vehicle technology will be developed from a societal construction of technology (SCOT) perspective, stating that human action shapes technology (Klein, Kleinnman, 2002). The SCOT framework may demonstrate the development of technology based on user needs, but it fails to address the findings of Brar and Caufield, who conducted a study on the impact of Autonomous Vehicles on pedestrian's safety. They found that the final measurements of "perceived safety" demonstrated that even supporters of autonomous vehicle technology do not feel comfortable with self-driving vehicles when they are in the position of the pedestrian navigating a crosswalk (Brar, Caufield, 2017). Engineers have taken the interests of both the driver and pedestrian into account, developing technology that will allow for the driver to safely and quickly navigate crosswalks as well as operate cautiously in urban environments (Schneemann, Gohl, 2016).

Certain cities are already finding loopholes around the lack of legislation restricting autonomous vehicles from roadways. Legal "guardrails" have allowed cities like San Francisco and Oakland to use data sharing amongst autonomous vehicles in order to improve roadway connectedness (Rodriguez, 2019). By inserting user-agreements, companies have created the ability to experiment with open autonomous vehicle communication, against the intentions of policymakers. Different social demographics will respond to privacy policy in unique ways. *Privacy implications and liability issues of autonomous vehicles,* attempts to address how certain social demographics will be harmed or potentially backlash against systems that expose user data to a larger public (Collingwood, 2017), making the public one of the most influential stakeholders in the implementation of autonomous vehicle technology. Engineers are accounting for concerns in privacy protection, creating systems with privacy-preserving efforts as the main objective (Hadian, Altuwaiyan, Liang, Zhu, 2019).

Studies conducted to predict the impact of Autonomous Vehicles and the ability to connect with one another have identified a potential to reduce the total amount of collisions on roadways. A particular study discusses predictive statistics behind how much safer autonomous vehicles would be on roadways without manually operated cars. The findings provide very significant percentages with regards to collisions that could have been prevented—some being as high as 90-94% deterrence (Papadoulis, Quddus, Imprialou, 2019). Another safety strategy as discussed within, *Assuring Fully Autonomous Vehicles Safety by Design: The Autonomous Vehicle Control (AVC) Module Strategy*, defined a way to develop a protection layer around the autonomous vehicle that is independent of the way the vehicles system was developed—similar to the techniques of machine learning (Molina et al., 2017). This information could provide argument that autonomous vehicle technology may develop on its own, with fewer and fewer needs for human input. As the technology continues to develop, algorithms that can detect and process outside information may be able to do so faster than human-created algorithms.

The studies conducted within *Privacy-Preserving Task Scheduling for Time-Sharing Services of Autonomous Vehicles*, demonstrate that efforts are being made to create a system with privacy-preserving efforts as the main goal (Hadian, Altuwaiyan, Liang, Zhu, 2019). This addresses a potential for privacy-breaching systems that would put users at higher risk. The legality of sharing user data among autonomous vehicle networks and party-sharing systems is outlined in *Privacy implications and liability issues of autonomous vehicles*, and describes how certain social demographics will be harmed or potentially backlash against systems that expose user data to large pools of users (Collingwood, 2017). The downside of party-sharing systems is that users no longer have the ability to move about in relative anonymity—making privacy nonexistent.

To outline the tentative structure of the STS research paper, the STS framework of the societal construction of technology and how it is incorporated in the development of American Policy with regards to Autonomous Vehicle technology on roadways will be the overreaching topic to address throughout the documentation analysis. A further breakdown of how each stakeholder in the problem (policymakers, engineers, and the public) will add to the SCOT framework will be included to organize sources and build a universal understanding of the situation. The tentative timeline for the paper involves further research on the future of the involved technology and how far away society is from major change, as well as diverting the writing away from addressing what background information already exists and focusing on the unique topic of what American Policymakers will face with the rapid development of Autonomous Vehicle technology.

RESEARCH QUESTION AND METHODS:

How are American Policymakers preparing for a future of autonomous vehicles with regards to protecting driver safety, privacy, and security?

To further evaluate this research question, I will employ documentary research method by finding sources of prior works related to autonomous vehicle studies. I will also use historical case studies to see the development of roadway safety and how autonomous vehicles have influenced statistics. With public information pertaining to the hearings within the Department of

Transportation congressional committees, I will be able to conduct policy analysis by looking deeper into the organization of autonomous vehicle classification and restriction. This will allow for analysis as to how far autonomous vehicles are from being implemented in society.

CONCLUSION

The technical deliverable associated with the VDOT SSP project is an updated route and scheduling sheet to optimize coverage of incidents and reduce response time. The research component will address the safety concerns of policy-makers, engineers, and the public by interpreting the interest of each stakeholder. The expected outcome from the research component will find a contrast between engineers pushing technology, policy-makers protecting industry and public safety, and the public/car owners ensuring low costs and high safety. The overreaching problem with this research question is finding an appropriate compromise for all of the stakeholders involved.

References

Beck, U., & Ritter, M. (1992). Risk society: Towards a new modernity. London: Sage Publications.

Brar, J. S., & Caulfield, B. (2017). Impact of autonomous vehicles on pedestrians' safety. *2017 IEEE 20th International Conference on Intelligent Transportation Systems (ITSC)*, 714–719. https://doi.org/10.1109/ITSC.2017.8317963

Collingwood, L. (2017). Privacy implications and liability issues of autonomous vehicles. *Information & Communications Technology Law*, *26*(1), 32–45. https://doi.org/10.1080/13600834.2017.1269871

Edara, P. K., & Dougald, L. E. (2006). Identification of Core Functions and Development of a Deployment Planning Tool for Safety Service Patrols in Virginia. 38.

Ferdowsi, A., Challita, U., Saad, W., & Mandayam, N. B. (2018). Robust Deep Reinforcement Learning for Security and Safety in Autonomous Vehicle Systems. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, 307–312. https://doi.org/10.1109/ITSC.2018.8569635

Gruber, F., & Althoff, M. (2018). Anytime Safety Verification of Autonomous Vehicles. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, 1708–1714. https://doi.org/10.1109/ITSC.2018.8569950

Hadian, M., Altuwaiyan, T., Liang, X., & Zhu, H. (2019). Privacy-Preserving Task Scheduling for Time-Sharing Services of Autonomous Vehicles. *IEEE Transactions on Vehicular Technology*, *68*(6), 5260–5270. https://doi.org/10.1109/TVT.2019.2909468

Heron, M. (2019). *Deaths: Leading Causes for 2017*. 77.

(Report No. DOT HS 812 069). Washington, DC: National Highway Traffic Safety Administration.

Klein, H. K., & Kleinman, D. L. (2002). The Social Construction of Technology: Structural Considerations. Science, Technology, & Human Values, 27(1), 28–52. https://doi.org/10.1177/016224390202700102

Molina, C. B. S. T., Almeida, J. R. de, Vismari, L. F., Gonzalez, R. I. R., Naufal, J. K., & Camargo, J. B. (2017). Assuring Fully Autonomous Vehicles Safety by Design: The Autonomous Vehicle Control (AVC) Module Strategy. *2017 47th Annual IEEE/IFIP International Conference on Dependable Systems and Networks Workshops (DSN-W)*, 16–21. https://doi.org/10.1109/DSN-W.2017.14

McCann, K. (2019, October 2). Personal Interview.

National Center for Statistics and Analysis. (2019, October). 2018 fatal motor vehicle crashes: Overview. (Traffic Safety Facts Research Note. Report No. DOT HS 812 826). Washington, DC: National Highway Traffic Safety Administration. Papadoulis, A., Quddus, M., & Imprialou, M. (2019). Evaluating the safety impact of connected and autonomous vehicles on motorways. A*ccident Analysis & Prevention*, *124*, 12–22. https://doi.org/10.1016/j.aap.2018.12.019

National Highway Traffic Safety Administration, NHTSA (2008). National Motor Vehicle Crash Causation Survey. U.S. Department of Transportation, Report DOT HS 811 059

Porter, M. (2019, October 2). Lecture.

Rodriguez, G. (2019). Autonomous Vehicles and Unmanned Aerial Systems: Data Collection and Liability [Leading Edge]. *IEEE Technology and Society Magazine*, *38*(3), 14–16. https://doi.org/10.1109/MTS.2019.2930264

Schneemann, F., & Gohl, I. (2016). Analyzing driver-pedestrian interaction at crosswalks: A contribution to autonomous driving in urban environments. *2016 IEEE Intelligent Vehicles Symposium (IV)*, 38–43. https://doi.org/10.1109/IVS.2016.7535361

Shuster, B., Young, D., Petri, T. E., Coble, H., Carolina, N., Duncan, J. J., … Hunter, D. (n.d.). COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE. *New York*, 89.

Truitt, D. (2019, October 2). Personal Interview.

Wang, H., Huang, Y., Khajepour, A., Zhang, Y., Rasekhipour, Y., & Cao, D. (2019). Crash Mitigation in Motion Planning for Autonomous Vehicles. *IEEE Transactions on Intelligent Transportation Systems*, *20*(9), 3313–3323. https://doi.org/10.1109/TITS.2018.2873921

Wang, Y., Liu, Z., Zuo, Z., Li, Z., Wang, L., & Luo, X. (2019). Trajectory Planning and Safety Assessment of Autonomous Vehicles Based on Motion Prediction and Model Predictive Control. *IEEE Transactions on Vehicular Technology*, *68*(9), 8546–8556. https://doi.org/10.1109/TVT.2019.2930684