Optimization of VDOT Safety Service Patrols to Improve VDOT Response to Incidents
(Technical Report)

Development of Autonomous Vehicle Technology: The Relationship Between Innovation and Legislation
(STS Topic)

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Author
Allison Hudak
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Technical Project Team Members
Elizabeth Campbell
Emma Chamberlayne
Julie Gawrylowicz
Collin Hood
Matthew Orlowsky
Emilio Rivero

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

Signed: ______________________

Approved: ______________________ **Date** 11/20/2019
Rider Foley, Department of Engineering and Society

Approved: ______________________ **Date** 12/2/2019
Michael Porter, Department of Engineering Systems and Environment

Introduction

The cost of congestion for United States citizens was nearly 87 billion dollars in 2018. This averages to a cost of 1,348 dollars and a loss of 97 hours per person. (Inrix, 2019) In Virginia, a major cause of these delays on interstate highways is traffic incidents such as crashes and disabled vehicles. These incidents create build up by blocking lanes or causing secondary accidents. The Virginia Department of Transportation (VDOT) addresses this problem through their Safety Service Patrol (SSP) Program. This program is an integral part of their overall traffic management strategy that focuses on traffic congestion and emergency response. The program started in the late 1960s in Northern Virginia and has now expanded to cover each of VDOT's five regions (Central, Eastern, Northern, Northwest, Southwest). (Safety Service Patrol, 2019) The program currently involves vehicles driving 50 patrol routes totaling approximately 891 miles. The main services the vehicles provide include detecting incidents and disruptions in traffic, clearing obstructions from the roadway, and establishing temporary traffic control. These services work to achieve the goal of responding to incidents quickly to minimize their disruption to traffic. VDOT records each incident into their Advanced Traffic Monitoring System through operators at Regional Traffic Operations Centers. Despite the SSP's importance in VDOT's traffic management strategy, the SSP routes were created using anecdotal data instead of incident report data. By not optimizing routes based on this data, VDOT cannot guarantee that the SSPs are effectively patrolling the areas that need the most assistance.

Technical Topic

This capstone will define data informed optimal routes for the SSPs specifically on I-95 and the connecting interstates such as I-495 and I-295. This impacts the Northern, Central, and

Eastern VDOT regions. Crash and incident data from 2013 to 2019 will be analyzed to develop predictive risk and severity models by time-of-day and day-of-week. This includes establishing the probability of an incident by mile across I-95 to identify trends and areas of high risk. The current patrol routing schedule and four previous routing schedules will be evaluated and compared based on the incidents that occurred within their respective time frames. Each route will be characterized based on the frequency of incidents on the route. The performance of the route will be measured by the median response time and median clearance time of the SSPs from the historical data. The response time is the time it takes from the SSP to arrive on the scene of the incident after being notified. The ideal response time would be zero, which indicates that the patrol of the SSP detected the incident. The clearance time refers to the amount of time taken from the report of the incident until the roadway is clear of the incident. This measure in important in measuring the ability of the SSPs to keep the roads clear. Recorded incidents that do not match to any route will also be explored to inform changes to the route schedule.

The analysis of risk and severity over time and the route evaluations will be combined into an optimization model. The output will be the recommended route schedules for the SSPs. This model will take into account budgetary and workforce constraints. Some constraints include accomodating to an eight hour work schedule and having a route length of about 30 miles in one direction. The team's goal is to have a preliminary route schedule in the first week of December. Adjustments will be made into the next year based on client input.

In addition to data analysis, visualization tools will be developed using the R software package R Shiny in order to effectively show incident risk, route schedules, and response time of SSPs to VDOT. A heat map visualization showing incident probability along interstate mile markers will be overlayed with the current and historical route coverage. This particular visualization will inform VDOT on the effectiveness of the SSP routes in high incident rate areas. The routes are effective if they match with the areas that historically have more incidents. Additional visualizations created will aid VDOT in understanding the final recommended changes to the route schedules such as adding, shifting, or splitting a route at certain mile markers. The visualizations will also provide a clear view of the implementation of recommendations. In reference to the goal of SSPs, the implementation of the recommendations will have the potential to reduce incident caused traffic congestion on I-95.

STS Topic

While the technical project is on route schedule optimization of SSPs, the STS topics will focus on the development of autonomous vehicles (AV). Both the technical project and the STS topic, however, relate to traffic management and driver safety. The SSP program clears traffic incidents to keep the routes clear and safe for travel. Similarly, the growth of AV technology has been greatly discussed in terms of its safety implications for society. According to the National Highway Safety Traffic Administration (NHTSA), human error is a major factor in 94 percent of fatal crashes in the United States. (NHTSA, 2019) AV technology has the potential to reduce these human error fatalities that occur in situations such as distracted driving, drunk driving, and drowsy driving. In addition, the impacts of traffic congestion is relevant to both the technical project and AVs. The use of AVs will allow productive use of time during a commute or a road trip. This translates to immense savings considering the 46.9 billion hours United States citizens spend driving each year. (Griffin, 2018) Other economic implications include the destruction and displacement of jobs from AV technology development. According to 2014 Census data, more than 4.4 million U.S. citizens over 16 years old work as professional drivers. (ibid) These implications need to be considered as AV technology increases its presence in society.

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
No Automation Zero autonomy; the driver performs all driving tasks.	Driver Assistance Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Partial Automation Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Conditional Automation Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	High Automation The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	Full Automation The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Table 1: Society of Automotive Engineers Automation Levels (Adapted from NHTSA).

AV technology is categorized in terms of automation levels developed by the Society of Automotive Engineers. These levels are summarized in Table 1 and range from “No Automation” at level zero to “Full Automation” at level five. This translates from a driver performing all of the tasks at level zero to the vehicle being able to perform all driving functions at level five. The middle level 3 requires the driver to be ready to take control of the vehicle if notified but they do not need to monitor the environment. (NHTSA, 2017) Other aspects of AV technology are vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. As their name suggests, V2V refers to the exchange of information between vehicles and V2I is the exchange of information between vehicles and their transportation infrastructure. (Marletto, 2019)

These AV technologies already exist today and there are over forty four companies developing their own versions of AVs. (Griffin, 2018) For the current market, Tesla autonomous vehicles are considered a Level 2. The fast pace in development suggests that the future market for autonomous vehicles will go directly to Level 5 vehicles and Level 3 will not be produced. Tesla and Google are examples of two major companies that are currently working on Level 5 autonomous vehicles. (ibid) Overall, the automakers in the AV technology industry will play a major role in determining the technology's impact and magnitude. The impacts depend on factors such as the level of automation, V2V and V2I connection, and business models. Examples of different business models include whether AVs will be owned, rented, or shared. (Marletto, 2019) The availability of this technology to consumers, however, is conditional on state and federal laws permitting it. In contrast to the rapid innovation in the industry, the legislation involving the regulation of AV technology is substantially slower.

The U.S. federal government has discussed several topics in regard to their role in AV technology development. One of the challenging decisions is the impact of regulation on innovation. The NHTSA has proposed a non-regulatory approach to advance the integration of AV technology into the transportation system. The NHTSA outlines a "Voluntary Safety Self-Assessment" for those within the industry of autonomous vehicles to demonstrate the safety of their AV technology to the public. The assessment is meant to show the public that industry stakeholders are considering safety aspects of their technology, collaborating with the Department of Transportation (DOT), promoting self-establishment of industry safety norms, and building public trust through transparent testing. (NHTSA, 2017)

The non-regulatory standard introduced by the NHTSA is not what the automotive industry wants in terms of policy. The industry is concerned with being able to circulate AVs into the market and standards are needed in order to make it possible. The "Self-Driving coalition for safer streets" was created by automakers including Ford, Google, Lyft, Uber, and

Volvo to promote clear national regulation. The coalition also acts as a collective industry force to advocate for the safety of autonomous vehicles to both lawmakers and the public. (Marletto, 2019) Overall, although the NHTSA recommendations are helpful to consider, they do not offer a prompt timeline that will unify manufacturer legal obligations across the national market. This points toward the responsibility of national legislation to be created. (Griffin, 2018)

The responsibilities between the Federal and State governments for motor vehicles are evolving in regard to AV technology. With conventional motor vehicles, the DOT and the Federal government regulate motor vehicles and motor vehicle equipment. The State governments regulate the human driver and other aspects of motor vehicle operation. Since AV technology now performs more of the human driver tasks, the DOT's authority to regulate the equipment safety will lead to incorporating concepts of the State government at the Federal level. One potential example is the licensing of a non-human "driver" such as the software or hardware in an AV. This can be compared to the licensing of a human driver at the State level. (Schuelke-Leech et. al, 2019)

The shift of responsibilities to a Federal level is also promoted for consistency reasons. The House Committee on Energy and Commerce has expressed that variance across states may create barriers or slow investment in autonomous vehicle technology. This was promoted the "SELF DRIVE Act" in the House, and later the "AV START Act" in the Senate. (Geistfeld, 2018) The discussion within these act concerns what legislation should be created at the Federal level. States such as California, Nevada, and Arizona are likely to influence the legislation since they were early adopters of autonomous vehicle testing. (Giffen, 2018) In any case, the Federal laws created must preempt conflicting laws at the State and local level. A balance between Federal and State laws may be found by bringing the laws that the majority of

States already hold to the Federal level. (Geistfeld, 2018) The consistency provided from Federal regulation will help define the path that advances the integration of AV technology.

The challenges of AV technology regulation are enhanced through the differences in priority between the government and industry. From a study on narrative consistency, measurable and qualitative differences were found between the discussions within Congress, public administration, and industry technologists. (Schuelke-Leech et. al, 2019) The difference was measured on indicators such as emerging vehicle technologies, driver responsibility, and technology failure. The results showed a low level concern in Congress on car technology failures and a high concern on vehicle safety. The discussions involving engineers, on the other hand, focused on the autonomous systems technologies and their development and commercialization. (ibid) This implies that future policy created may not adequately account for the priorities of industry. The focus on certain priorities in general can lead to a lack of consideration of other implications due to AV technology regulation.

The development of AV technology will be analyzed through Hughes' technological momentum framework. This framework defines a pattern pertaining to systems that evolve and expand over time. (Hughes, 1987). Applying the framework to AV technology will help define the current state and the evolution of this technology with respect to the technological system. The pattern of evolution is presented as a combination of phases including invention, development, growth, and consolidation. Hughes claims that as technological systems become larger through growth and consolidation, they acquire momentum. A result of these larger and more mature systems is that it is more challenging to control their use in society. This concept can also be defined as an exercise of soft determinism on society and other systems. (ibid) With the rapid pace of innovation of AV technology, it is crucial for the key stakeholders to consider the implications of its integration into society. As integration increases, the matching increase in momentum may make the use of AV technology too difficult to influence or change.

Research Question and Methods

The research question informed by the previous discussion is how will the relationship between the federal government and the automotive industry impact the development of autonomous vehicles in the United States? This question is important as it aims to create insight into the safe and responsible development of AV technology through regulation. In order to explore the question, policy documents and will be collected as a secondary source of evidence. The policy documents will be from Federal and State governments and other regulatory entities such as the DOT and NHTSA. The documents selected should focus on defining the government's role in AV technology. Examples of policy documents include the Senate's "AV START act" and NHTSA's proposed standard of V2V communication. (Gestfield, 2018) Evidence from the industry side will be collected through white papers and reported safety evaluations from the automotive industry. One example that could be used is the "Safety First For Automated Driving" white paper published by industry stakeholders including BMW, Audi, and Volkswagen. (Wood, 2019).

The evidence will be evaluated through a combination of policy and content analysis. The policy analysis will aim to describe the context and the effectiveness of the outcomes for recent AV technology policy. The analysis will generate understanding in why these policies either were or were not enacted. This provides insight into the prediction of future policy discussions and informs potential recommendations. Content analysis will also be used on both the automotive industry evidence and policy evidence gathered. Themes and patterns extracted from content analysis will be used to describe the industry's position in how to integrate AV technology. Differing from the policy analysis, the content analysis on the policy documents will focus on recognizing patterns among the documents rather than analyzing the policy's effectiveness. As a whole, the analysis techniques will describe the current government and industry position within the development of AV technology and characterize the implications of their similarities and differences for the future.

Conclusion

The research for the STS topic will be used for an analysis on the Federal government and automotive industry relationship in regard to AV technology. This technology is rapidly advancing and pressuring government action which is historically time intensive. Any action taken will have great implications on society which will become more difficult to control as AV technology gains momentum. The completion of this analysis has the potential to provide insight into these implications and inform government and industry stakeholders how to cooperate.

The timeline to complete the thesis includes gathering the evidence, performing the analysis, outlining, and creating drafts. The evidence will be gathered by the beginning of December and analyzed by the beginning of January. The analysis will be formatted into an in depth outline and written into a first rough draft by the end of February. The thesis will be edited and peer reviewed in the first half of March. The second half of March will be to refine the final draft of the thesis with the goal to be completed in the last week of March.

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