DEVELOPMENT OF AN AUTONOMOUS DRIVING SIMULATOR

A POLICY ANALYSIS REGARDING ADOPTION OF ELECTRIC AND AUTONOMOUS VEHICLES IN THE UNITED STATES AND EUROPE

A Thesis Prospectus

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By

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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.

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General Research Problem

What are the societal/political differences between attitudes towards EV/AV adoption in the US vs. Europe?

The emergence of autonomous vehicles has ushered in a new era of transportation, promising a plethora of benefits but also presenting a host of challenges. Autonomous vehicles have the capacity to significantly minimize the number of accidents caused by human error, improve safety, and reduce traffic, offering a glimpse of a future with fewer road fatalities and injuries. Moreover, they have the potential to improve fuel efficiency and lower emissions, contributing to a greener and more sustainable environment. However, despite these promising advantages, the widespread adoption of autonomous vehicles has been impeded by a series of complex challenges. Concerns regarding cybersecurity vulnerabilities, ethical dilemmas related to decision-making in critical situations, and the high costs associated with the development and implementation of this technology have posed significant roadblocks.

Since these concepts are very novel, much more research must be done to develop a full understanding of their benefits and potential consequences. In particular, testing framework and regulatory standards need to be developed in order to create the needed infrastructure for AVs. Many states do not allow companies to test AVs on public roads without a test driver, which severely limits the variety of situations a test can be conducted in without endangering the driver or other cars on the road (Favaró, Eurich, & Rizvi, 2019). If the AV does get into an accident or malfunctions, repairs cost valuable time and money. This is an area that can be improved by autonomous driving simulators (ADS). An ADS allows engineers the ability to quickly conduct performance assessments on AV software in a safe, controlled environment. Being able to test AVs in a wide range of environments allows engineers to make the software safer and improve usability as well.

In regard to the public perception of AVs, looking at how EVs have been received can allow us to understand the successes and shortcomings of new transportation technology. EVs and AVs have been closely linked since their inception. Tesla has pushed the boundaries of AV technology with their Autopilot feature, and companies like Ford and GM are incorporating more advanced driver assistance and autonomous features into their next generation electric cars. However, electric vehicles have faced obstacles in their adoption in the US. Compared to Europe and China, EVs lag significantly behind in market penetration due to many factors (Colato & Ice, 2023). What are these countries doing differently to promote the EV transition?

In this research project, I will aim to uncover the successful methods employed by car manufacturers and other countries in the EV transition and relate those successes to the autonomous and electric vehicle market in the US, as well as investigate improvements to testing technology that will help to make autonomous vehicles safer.

Technical Research Question: Integration of CARLA and Autonomous Driving Software with a Driving Simulator

How can we use an autonomous driving simulator to better study autonomous software?

My technical project is enhancing the UVA Virginia Cooperative Autonomous Robotics lab's autonomous driving simulator. Specifically, my team will create a haptic feedback system and install additional sensors that will assist drivers using semi-autonomous vehicles. We are also integrating the Car Learning to Act (CARLA) simulation program, which provides realistic simulation environments, open-source autonomous driving algorithms, and an interface to conduct performance assessments of autonomous driving systems. Since autonomous driving is a very novel technology that has not be thoroughly researched, many states have restrictions on the level of autonomous driving that is allowed on public roads. Oftentimes, when manufacturers test their autonomous driving systems on the roads, it must be done in a controlled manner with a trained driver supervising the vehicle, and the driver must be ready to take control of the vehicle in case of any software or hardware malfunction (Favaró, Eurich, & Rizvi, 2019). While the driver does provide an additional layer of security to prevent dangerous accidents from occurring, it also limits the severity of testing situations that can be safely simulated with a human in the car. The benefit of a driving simulator is that autonomous driving technology can be tested in a wider range of situations in a controlled environment without endangering other vehicles or people in the process. With the addition of CARLA to the driving simulator, we will be able to import large realistic environments that closely replicate how the autonomous driving system will operate in the real world. CARLA has a repository of highways, highway interchanges, intersections, and city environments available that can also be modified to test how the software would react in dangerous situations.

Compared to the current software on the simulator, CARLA combines physics simulation and graphical rendering into one package. Previous generations of the simulator software used OpenDS to calculate the physics and send commands to the simulator platform and Gazebo for the graphics rendering. Running both programs simultaneously on one computer is a CPU and GPU intensive process. The current hardware is outdated as well, and these issues compound, resulting in latency between user input and actuation of the simulator platform, low graphical resolution, and lag when displaying the simulated environment. We expect CARLA to reduce the lag, latency, and processing load required to simulate graphics and physics. To increase realism and provide some futureproofing, we will also be building a new computer using state-of-the-art hardware.

Furthermore, CARLA has the ability to interface with sensors commonly used on cars, such as ultrasonic sensors and GPS, as well as advanced sensors dedicated to autonomous vehicles. Combined with the driving simulator, we can also conduct performance assessments for the sensors and understand how the autonomous software uses sensor information. Testing the sensor and autonomous driving software interactions on a road car is often very difficult. The simulator will allow us to study sensors that we can program to simulate real life traffic and evaluate if the autonomous driving software is correctly using the data.

An autonomous driving system will be able to use its entire suite of advanced sensors to map out its environment and safely maneuver the vehicle through all different kinds of scenarios. This technology has many positive benefits, such as allowing the disabled the ability to use a car, the autopilot function on long car trips, and the software's ability to react to potential accidents faster than a human driver can (Petrović, Mijailović, & Pešić, 2022) (Favaró, Eurich, & Rizvi, 2019). This simulator and the CARLA technology have the potential to advance the field of autonomous driving research by allowing researchers a platform to safely conduct performance assessments in a controlled manner. In addition, driver assistance packages can also be installed and tested, such as haptic feedback that relays information to the driver, a heads-up display that can warn the driver through safety messages, and software allowing the car to assist the driver in potentially dangerous situations. This simulator will ensure that all autonomous technology is thoroughly tested before it is released onto the market. The simulator can also be used as a platform to gauge public perception of AVs using public test trials and surveys, to build a complete understanding of AV technology.

STS Research Topic: Comparison of US and European Policies Regarding Adoption of Electric and Autonomous Vehicles

In what ways are the fiscal policies on EVs between the US, Europe, and China different and how do they affect EV market performance?

A technology's adoption is not only defined by how well it functions objectively, but also by the value it holds for its consumers. If people adopt a technology based only on the former, everyone would be driving the most efficient and affordable vehicles, but this is not the case. There are certain unique subjective values that each person has that affect their decision making, leading to the diverse car market that we see today. Relating this to EVs, each person has their own opinions about them based on factors such as the state of the infrastructure where they live and the social norms present at the time, among other reasons (Dieleman, Dijst, & Burghouwt, 2002). These opinions and factors affect people's reasons for choosing to switch to EVs. However, with the new wave of environmentalism and sustainability initiatives in developed countries, policymaking is now also affecting how people choose their cars (Rietmann & Lieven, 2018). Like how people base their decisions off of how they view a technology, the policymaking of a country also reflects this and shows what values are important to its citizens. In this STS research paper, I want to investigate how different values of a country on EVs affects its policymaking, and how this affects the way people make decisions.

Background

Differences between the United States and Europe manifest themselves in many ways that are commonly seen in everyday life. In the context of this investigation, the main difference between European countries and the US is size and geography. With different environmental and social factors, the way these two countries place value on technology would be different considering the importance of gas-powered cars. For example, European cities often have well-established public transportation systems and compact urban designs that are conducive to alternative transportation modes, including EVs. This infrastructure can facilitate the integration of EVs into existing public transit networks and promote sustainable mobility solutions. There is less of an emphasis placed on gas-powered cars because there are other methods of transportation that can accomplish the same task but emphasize different values, such as affordability and sustainability.

In the United States, urban planning is often centered around automobile usage, leading to extensive road networks and a reliance on personal vehicles. This dependence on cars may influence the perception and adoption of EVs, as well as the need for infrastructure development to support widespread electric vehicle use (Santos & Davies, 2020). This illustrates the mutual shaping of technology and society. For example, since the total number of EVs on the road is very small, the number of EV charging stations and EV infrastructure is poorly developed. This reaffirms the concerns about range anxiety and affects policymaking.

These differences in social norms also create a difference in the policies that can be implemented in those counties. In Europe, some countries are requiring car manufacturers to meet a certain quota or meet carbon emission goals by a certain year in the future. Legislation in Norway and the Netherlands are phasing out all gas-powered vehicles by 2025 and 2030, respectively. This has been extremely effective in penetrating the car market, where around 80% of all new vehicles sold are EVs (IEA, 2023) (Chappell, 2021). This is only possible if the values of the citizens reflect and support those policies. If the public was dissatisfied with these policies, there would be discernible indicators, such as an increase in the number of imported cars, or a decrease in percentage of cars sold that are EVs.

Meanwhile, the United States has been very conservative in terms of EV policymaking. Companies based in the US, including Ford and GM, have agreed to phase out gas-powered cars by 2040, but this initiative has not been taken federally (UNFCCC. Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA), 2021). This is possibly due to lack of support from individual states, where EVs have not yet proven themselves more valuable than gas-powered cars. Considering the scale of the United States, there are also geographical differences, such as mountain ranges, rural land areas that can affect the local perception of EVs and small scale (urban sprawl, long travel distances) that prevents the US from making the same policy changes as countries elsewhere (Wickham, 2006) (Dieleman, Dijst, & Burghouwt, 2002). However, states like California are very progressive in policymaking; with the recent establishment of ultra-low emission zones in certain cities, they rival European progressivism. The nucleation of said progressive policies in single US states illustrates that there are certain infrastructures and norms in place that allow for a successful transition, but this has not spread across the country. What are these states doing differently in terms of policymaking or promoting certain technologies that affects the civic epistemology of their residents?

Theoretical Framework

Many of the factors affecting the EV transition are based on the civic epistemology that is unique to every country as a result of different geography and social norms. Civic epistemology is an interdisciplinary field that examines how knowledge is created, disseminated, and applied within civic contexts. It investigates how communities, institutions, and individuals generate, validate, and utilize knowledge to address social issues and promote democratic participation (Jasanoff, 2005). This framework would analyze how the values of a country mutually shape its policies regarding technologies.

Methods: Evidence/Data Collection and Analysis

To conduct this research, I will first analyze the policies relating EVs and EV infrastructure of one or two successful US states and one or two European countries that have had relative success in the EV transition. In this case, success in the transition would be defined as a significant shift away from gas-powered cars, measured by the proportion of EVs compared to gas cars, or a large increase in sales of EVs at the end of each fiscal year. After understanding what policies promote EV sales, I will then compare these policies to one or two states that have poor EV adoption. In these cases, it is also important to establish a background understanding of the transportation infrastructure as well. To understand public perception and the value that EVs have for the population, surveys and the census would provide the necessary data.

Conclusion

The comparative analysis of societal and political attitudes toward electric and autonomous vehicle (EV/AV) adoption in the United States and Europe highlights the mutual shaping of cultural norms, infrastructure development, and policy frameworks. European nations, driven by a strong commitment to sustainability, have implemented ambitious policies and incentives, leading to a notable surge in EV adoption. Compact urban designs and robust public transportation systems have further facilitated the integration of EVs into existing transit networks. In contrast, the United States, with its deeply ingrained car culture and expansive road networks, faces challenges in widespread EV adoption, leading to a more fragmented approach across different states. These disparities underscore the importance of considering the values that these technologies hold in order to understand their success.

The technical section of the research project focuses on the integration of the CARLA simulation program with the UVA Virginia Cooperative Autonomous Robotics lab's autonomous driving simulator. This integration aims to enhance the simulator's capabilities by implementing a haptic feedback system and installing additional sensors. By leveraging CARLA's high-fidelity simulation environments and open-source autonomous driving algorithms, researchers can conduct comprehensive performance assessments and evaluate the software's response to various real-world driving scenarios, contributing to the advancement of autonomous driving research. The use of advanced hardware and sensor technologies underscores the commitment to creating a robust and reliable platform for conducting thorough evaluations of autonomous driving systems, thereby enhancing overall safety and performance assessments.

Through the combination of these conclusions, it becomes evident that both societal and technical aspects play a critical role in shaping the trajectory of EV/AV adoption. Acknowledging the interplay between cultural norms, policy frameworks, and technological advancements is imperative in fostering sustainable and efficient mobility solutions that cater to the diverse needs and values of different regions. By leveraging collaborative decision-making processes and integrating cutting-edge technologies, the research community can contribute significantly to the development of a more inclusive, safer, and advanced transportation ecosystem for the future.

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