Instituting a Plan for Sustainable Transport in the University of Virginia, Charlottesville, and Albemarle County

(Technical Paper)

The Pursuit of Automobile Computerization and Modernization Despite Cyber Risk

(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

Goutham Subramanian Thiagarajan

Spring, 2020

Technical Project Team Members

Isabel Markus

Chelsea Wells

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

Signature _____ Date _____

Goutham Subramanian Thiagarajan

Approved _____ Date _____

James Groves, Department of Engineering and Society

Approved _____ Date _____

Kathryn A. Neeley, Associate Professor of STS, Department of Engineering and Society

Introduction:

Motor vehicles have been the most common form of transportation for over a century. Given the utter dependence of modern society on motor vehicles, it is imperative that future vehicle designs prioritize environmental friendliness and cybersecurity. The majority of motor vehicles that are in use run on internal combustion engines that combust fossil fuels, which contribute to greenhouse gas (GHG) emissions and a warmer planet. In 2017, the largest contributor of U.S. GHG emissions was transportation, accounting for about 28.9 percent (Environmental Protection Agency, 2019b, n.p.). The impact of transportation on GHG emissions can also be seen at a more local level as emissions due to transportation have increased 33.8 percent from 2009 to 2018 at the University of Virginia (UVA) (Pettit, 2019, p. 7). Transportation also has significant economic, social, and environmental impacts on sustainability. The pursuit of global sustainability is desirable as it allows for needs of the present to be met "without compromising the ability of future generations to meet their own needs" (Jeon & Amekudzi, 2005, p. 31). At the same time, the modernization of automobiles has led to them becoming cyber-physical systems (CPSs), which are integrations of computation, networking, and physical processes. However, a CPS requires cybersecurity that is resilient, promotes privacy, protects against malicious attacks, and detects intrusion (Ptolemy Project, 2019). Automobiles have become targets for cyberattacks as they become increasingly connected. Possible vehicle cybersecurity attacks can be disruptive as they include engine shutdowns, disabled brakes, and locked doors (Hashem Eiza & Ni, 2017, p. 45).

Buses are a mode of transportation that is of interest with regards to sustainability because of their high passenger capacity and accessibility and with regards to cybersecurity because of their increased computerization. However, it is unclear whether making a bus

cybersecure negatively affects its environmental friendliness or vice versa. For example, vehicles that are nontraditional are usually more expensive to consumers. If buses are electrified when there is a possibility that they may have a negligible or more negative impact on the environment, then the extra energy costs involved in production, operation, and disposal can be avoided. There may also be a chance that these modifications increase vulnerability to cyberattacks.

My technical work aims to investigate the pros and cons of focusing renewable energy efforts on buses. My capstone group is currently designing a solution to promote and expand sustainable transportation in the Charlottesville/Albemarle County region. The strategy that my group develops will help the area transition to renewable energy as the main source of fuel for transportation and also make the transportation system more efficient, reliable, and accessible for residents. If successful, this local strategy could be promoted in other cities or counties of a similar size to have a larger global impact. The STS work will investigate cybersecurity and examine the advantages of making bus systems more computerized while mitigating security risks. The computerization of vehicles has greatly improved the quality of life for drivers and passengers with safety features and assistive technologies; however, these advancements have likely opened the door to vulnerabilities.

A Plan for Sustainable Transport: Its Necessity and Potential Obstacles

As mentioned previously, transport is a major contributor to GHG emissions. Personal vehicles compound the problem as light-duty vehicles contributed to 59 percent of all transportation GHG emissions in the U.S. in 2017, while buses comprise at most 4 percent (Environmental Protection Agency, 2019a). GHGs have an undeniably negative impact on the environment; however, convenience and availability, among other factors, make it extremely

difficult to eschew personal vehicles. Compared to personal vehicles, buses are "highly efficient passenger transport modes with low levels of fuel consumption even when occupancy is around 20%, thus providing modest carbon dioxide and other GHG emissions" (Corazza, Guida, Musso, & Tozzi, 2016, p. 21). If on newer, no-oil propulsion technologies, this efficiency is further enhanced. Empirical evidence shows that buses are still competitive in reducing harmful emission even when passenger car occupancy increases. Within cities, buses are among the most space-efficient modes of travel within cities and "do not require heavy infrastructure" (Corazza et al., 2016, p. 22). However, there is not a consensus on the most effective means to better bus services despite different developments in bus system service improvement (Fernandez-Sanchez & Fernandez-Heredia, 2018, p. 1).

However, using renewable energy sources for both personal vehicles and many-passenger vehicles such as buses can help mitigate the effects of climate change. One of the goals of my capstone group is to expedite the process of transitioning the transportation sector to renewable energy in Charlottesville and Albemarle County. Renewable resources are key to sustainability and already comprise a significant portion of global energy consumption. By the end of 2018, the "estimated share of renewables in global electricity generation was more than 26%" (REN21, 2019, p. 17). According to the International Energy Agency (2012), the deployment of renewable energy technologies has already resulted in energy security, climate change mitigation, and economic benefits. The emergence of renewable energy as a viable option has also generated millions of jobs and decreased dependence on fossil fuels.

However, green technologies are not without issues. Corazza et al. (2016) make the point that the availability of clean technologies represents the link between environmental care and economic concern. For example, while hybrid or electric buses have the potential to reduce

emissions, they are more expensive than the conventional ones that use an internal combustion engine. Thus, affordability can limit the wider adoption of cleaner engines. Another issue is that technological development of eco-products in general is "faster than the regulatory process which such development should support, but far beyond the real demand to implement such products" (Corazza et al., 2016, p. 28). This implies that vehicles that are state-of-the-art and highly eco-efficient may only have a demand that is theoretical and potential. A final issue is that companies may act in their own interest with the goal of maximizing their financial gain. Making buses more sustainable is desirable and worthwhile but any solution that my capstone group develops must take these issues into account.

By discovering or creating sustainable transportation solutions in Albemarle and Charlottesville, my capstone group desires to help those in the area who travel while also keeping the environment in mind. With improved public transportation, residents can have lower transportation costs since they will not need to pay for gas for their personal vehicles or pay for personal parking spots. In addition, addressing this challenge will expedite the process of transitioning to renewable energy for the transportation sector at a local level, which can help slow climate change.

Cyber Risk: A Potential Disadvantage of Vehicle Computerization

For much of the past century, vehicles were machines that were separate and wholly mechanical with the sole purpose of transportation. As concepts such as the Internet of Things grow in popularity, "consumers increasingly demand a seamless connected experience in all aspects of their lives including driving" (Hashem Eiza & Ni, 2017, p. 45). Smartphones, which themselves have only become commonplace over the past decade, are already integrable with most modern models of cars. Vehicles themselves are now "controlled by hundreds of electrical

control units (ECUs) that form an internal network of devices within the vehicle" (Hashem Eiza & Ni, 2017, p. 46). Vehicles are also capable of communicating with each other or with infrastructure, and this connection is microcosmic of a connected world. Although increasing connectivity and autonomy in vehicles potentially leads to greater convenience and functionality, it likely also leads to new cyberthreats.

In a notable incident in July 2015, two researchers demonstrated the feasibility of a cyberattack on an automobile when they hacked into a Jeep Cherokee that was on a highway ten miles away (Greenberg, 2015). By exploiting a software known as Uconnect, the researchers were able to remotely control the car functions using a simple third-generation (3G) connection. Using this vulnerability as an attacking entry point, they were able to rewrite the firmware of the adjacent chip in the car's head unit and disable the brakes, control the steering wheel, and send the vehicle into a ditch. This incident caused the recall of 1.4 million cars (Hashem Eiza & Ni, 2017, p. 46). Moreover, it represents a proof of concept that physical access to the car is no longer necessary to hack into it. It would appear that a hacker needs only to be in communication range of a vehicle to possibly take control of its most critical functions. For example, "a simple and sudden airbag deployment while driving on a highway represents a lethal cyberattack that could cause the vehicle to crash and claim lives" (Hashem Eiza & Ni, 2017, p. 46). Understanding cyberthreat vectors against vehicles can help identify attack entry points. These can be seen in the figure below and include commonly used technologies such as Wi-Fi, Bluetooth, USBs, and GPS (Petit & Shladover, 2015, p. 6).

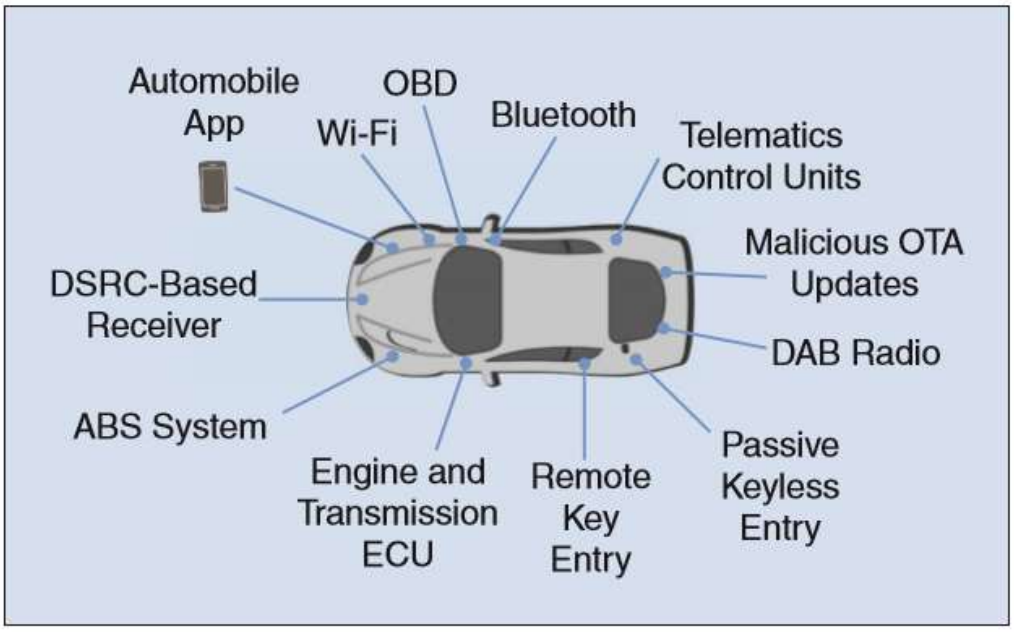

Figure 1: An illustration of the potential vectors of cyberattacks in a car. These include well-known technologies such as Wi-Fi, Bluetooth, and apps as well as lesser-known ones. (Hashem Eiza & Ni, 2017, p. 46)

However, what is most likely to be relevant to my STS research are the actors involved in solving this problem. Hashem Eiza and Ni (2017) note that it is not feasible to design one security solution for the whole system because ECUs usually come from different vendors (p. 50). The National Highway Traffic Safety Administration (2016) takes a layered approach to cybersecurity with four main focuses: isolating affected subsystems to reduce the effects of a successful attack, using intrusion-detection measures that are real-time, preserving the ability of the driver to control the vehicle after an attack, and using information from previous attacks to evaluate existing protection mechanisms (p. 10). New features are continuously added to vehicles by manufacturers, but cybersecurity should not be neglected given that there are human lives at stake. My STS research aims to discover how various seemingly unrelated entities such as academia, the auto industry, and governments work together or independently to tackle this issue. By doing so, I hope to gain a better understanding of the organizations involved in this issue and what their motives are.

Conclusion:

My capstone group intends to improve the local public transportation system by focusing on renewable energy and the three criteria of efficiency, reliability, and accessibility. To achieve this goal, my technical work will produce a design to promote sustainability in transportation in the Charlottesville area. My deliverable for STS research will be a better understanding of whether the computerization of cars is something that is worth continuing to pursue based on the risks involved and the organizations working on a solution. If both projects are successful, then they will illuminate the role of motor vehicles, specifically buses, as systems that are sustainable and cybersecure, two areas that are important and potentially overlapping in modern society.

References:

Corazza, M. V., Guida, U., Musso, A., & Tozzi, M. (2016). A New Generation of Buses to Support More Sustainable Urban Transport Policies: A Path Towards "Greener" Awareness Among Bus Stakeholders in Europe. *Research in Transportation Economics*, **55**, 20 - 29. doi: 10.1016/j.retrec.2016.04.007

Environmental Protection Agency. (2019a). Fast Facts on Transportation Greenhouse Gas Emissions. Retrieved from https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.

Environmental Protection Agency. (2019b). Sources of Greenhouse Gas Emissions. Retrieved from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation.

Fernandez-Sanchez, G., & Fernandez-Heredia, A. (2018). Strategic Thinking for Sustainability: A Review of 10 Strategies for Sustainable Mobility by Bus for Cities. *Sustainability*, **10**(11), 0 - 14. doi: 10.3390/su10114282

Greenberg, A. (2015, July 21). Hackers Remotely Kill a Jeep on the Highway-With Me in It. Retrieved from https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/.

Hashem Eiza, M., & Ni, Q. (2017). Driving with sharks: Rethinking connected vehicles with vehicle cybersecurity. *IEEE Vehicular Technology Magazine*. 12(2), 45 - 51. doi: 10.1109/MVT.2017.2669348

International Energy Agency. (2012). Energy Technological Perspectives 2012: Pathways to a Clean Energy System. Retrieved from https://www.iea.org/Textbase/npsum/ETP2012SUM.pdf

Jeon, C & Amekudzi, A. (2005). Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. *Journal of Infrastructure Systems*. 11. doi: 10.1061/(ASCE)1076-0342(2005)11:1(31)

National Highway Traffic Safety Administration. (2016, October). Cybersecurity best practices for modern vehicles. (Report No. DOT HS 812 333). Retrieved from https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812333_cybersecurityformodernvehicles.pdf

Petit, J., & Shladover, S. E. (2015). Potential cyberattacks on automated vehicles. *IEEE Transactions on Intelligent Transportation Systems*, 16(2), 546-556. doi: 10.1109/TITS.2014.2342271

Pettit, A. (2019, July). UVA 2018 Greenhouse Gas Inventory. Retrieved from https://sustainability.virginia.edu/sites/sustainability/files/2019-08/Greenhouse-Gas-Inventory-Report-UVA-CY2018.pdf

Ptolemy Project. (2019). Cyber-Physical Systems – a Concept Map. Retrieved from https://ptolemy.berkeley.edu/projects/cps/.

REN21. (2019). Renewables 2019: Global Status Report. Retrieved from https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf