

Undergraduate Thesis Prospectus

Streamlining Golf Cart Use: An Automated Platooning System for Golf Carts

(technical research project in Mechanical Engineering)

Battery Powered Electric Vehicles: How Various

Stakeholders are Affecting the United States Automotive Industry

(sociotechnical research project)

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

How is the automotive industry responding to climate change?

Climate change is a relevant problem for the following reasons: extreme changes in weather and weather events, effects on human health, sea level rising, and general changing of ecosystems (EPA, 2022). Globally, 31 gigatons of greenhouse gas (GHG) emissions are produced each year; the US alone accounts for 6.34 billion tons of the GHG emissions (CDP; EPA 2023). According to the United States Environmental Protection Agency (EPA), 29% of US GHG emissions come from the transportation industry (EPA, 2023a). Thus, there needs to be change in the industry to significantly reduce GHG emissions.

Streamlining Golf Cart Use: An Automated Platooning System for Golf Carts

How can we automate golf carts for usage on golf courses?

The goal is to get 3 golf carts automatically following a manually driven car. My capstone advisor is Tomonari Furukawa in the Mechanical and Aerospace Engineering department. This is a group project with the following student collaborators: Rachel Thirumalai, Santiago Merida, Carolyn Pitorak, Ben Tharakan, and Riley Tufts.

Platooning is a form of automated driving where vehicles' motions are linked with one another to move based on predictive models to find the optimal path. Advantages of platooning include: reduced accidents, increased traffic efficiency, increased fuel efficiency, and increased independence for the disabled and those with reduced mobility (US FHWA, 2021). Early testing with truck platooning has proven 10% savings in fuel spending and CO₂ emissions (US FHWA, 2021; ACEA 2021). Implementing a successful platooning system on the campus vehicles will prove that it has the potential to increase student mobility; and that platooning at a larger scale is both possible and safe.

We hope to add a third car to the current two-car platooning system that currently exists and implement a probabilistic platooning model instead of the current platooning software. To achieve this, we will install new hardware and software on all 3 carts. We will test each car individually to ensure sensors are functioning and that the vehicles can determine the difference between foreign objects and leader carts. At the end of the project, we hope to have a manually driven leader cart that is connected to two follower carts whose optimal path is determined using the relative position of each car, the angle at which it is driving, and impedances to its current path. The success of this project affects how platooning systems may be implemented in the real world. The project hopes to be expanded for further campus use to shuttle students around.

The Competition for the Future of Battery-Electric Vehicles in the United States

How are minerals companies, energy companies, automakers, and NGOs competing to determine the place of battery-electric vehicles in the transport transition and the conditions under which the necessary battery minerals will be obtained?

How can the automotive industry become “greener”? The US wants to achieve this by using EV’s; however, there are concerns about how the battery industry will transition. About 70% of cobalt – a necessary mineral for batteries – is located in the Democratic Republic of the Congo (DRC), and mining cobalt poses threats to both the natural and human environment (Tabuchi, 2021). Cobalt mining uses machinery that contributes to GHG emissions, releases excess nitrogen dust, and produces carcinogenic pollutants (Laezman, 2023). The artisanal and small-scale mining that cobalt mining requires has also been known to violate human rights (Laezman, 2023). Similarly, lithium mining in the “Lithium Triangle” of Chile, Argentina, and Bolivia requires excessive amounts of water that cause extreme water shortages, contaminate water, and hinder farmers ability to “grow crops and maintain live-stock” (Ahmad, 2020). PACT,

a nonprofit supporting African mining companies, expressed concerns about the environment and miners in the Congo (Tabuchi, 2021). How have the concerns with the battery-EV transition affected the progression to a “greener” future?

The concerns about the use of rare minerals has been deterred by various researchers. The Union of Concerned Scientists claim that by 2035, the battery industry hopes to reduce their cobalt use in kg per 100kWh from 28 percent, from 2018, to 10 percent (Ambrose and O’Dea, 2021). Another concept promoted to reduce mining is recycling batteries, which “reduces the need for extracting, refining, and transporting new minerals” (Ambrose and O’Dea, 2021). These recycled batteries can be used in lower-power applications. What is the human cost associated with mining in countries where regulatory bodies restrictions aren’t enforced?

The important voices are the miners themselves. In an article written by the Washington Post, we hear from several people involved in the mining community of the DRC: Alain Kasongo, Patrick Kazadi Mumba, and Rock Makina Mununga. Kasongo, a 43-year-old miner, who suffered back pain from operating heavy machinery, said “it hurt so badly when I went home, I would lie awake at night” (Houreld, 2023). Mumba, a neurologist from Lubumbashi, reported that he saw an unusual rate of young people with spinal problems (Houreld, 2023). Miners work 12 hour shifts for 6 days in a row, many of them not reporting injury until surgery was necessary. These employees, after being injured, are either given tasks they cannot complete or are forced to find a new job, which they can’t pass the health exams for (Houreld, 2023). Mununga, a former truck driver for Tenke Fungurume, said he “was in good health before my job,” but “now I can’t walk well, I can’t work, I can’t provide for my family” (Houreld, 2023). In 2016, Amnesty International released a report revealing governments of these mining countries have failed to recognize and enforce their own labor standards (Amnesty International, 2021).

The report reveals that child labor exists and “the government has yet to remove financial and other barriers that children face in accessing primary education.” Amnesty urges the companies who recognize these human rights violations to not discontinue the relationship, but “take action to remediate the harm suffered by the people affected’ (Amnesty International 2021).

Lastly, the cost and life-cycle of lithium batteries pose a challenge in making these EV’s cost effective (Cheng et al., 2011). According to researchers Erickson and Brase, there are two methods to reduce GHGs which should be used together: shifting to EV’s or changing electricity generation methods. Though there are cost concerns associated with making the transition from internal combustion engines (ICE) to EV’s, they state a number of reasons as to why these are avoidable: 1) The costs of batteries are projected to decline from \$200/kWh to \$70/kWh by 2025. 2) Maintenance costs for BEV’s are lower than those of ICE vehicles because BEV’s have fewer pieces involved in the drive-train. 3) BEV’s save energy by converting potential and kinetic energy into electricity by regenerative braking. 4) Though total cost of ownership (TCO) varies across geographical locations, the discontinuity between TCO’s is the cost of petroleum (Erickson and Brase, 2019). With a global goal of decreased petroleum production in the future due to climate concerns, the cost might increase, making the TCO of a BEV less than an ICE anywhere. Other researchers have stated that “if the electricity is generated from fossil fuels, the electric car remains competitive only if the electricity is generated onboard” (Pistoia et al., 2010). Both papers avert the warnings of cost and specify when the BEV’s become advantages from a GHG perspective.

Participants include various nongovernmental organizations that claim to support the energy transition. The Electric Vehicle Association (EVA), a non profit organization supporting the transition to EV’s, however, promotes the cost savings of EV’s (Gerke, 2023). Conversely,

there are various researchers and professional organizations that counteract the work of the EVA by claiming the long term benefits don't outweigh the initial spend. The Institute of Electrical and Electronics Engineers (IEEE) shared via Spectrum, a publication of theirs, that the amount of vehicles needing to be replaced by EV's is too high to be feasible (Charette, 2023). Lastly, MIT and Argonne National Lab researchers concluded that the battery technology is too expensive to sustain replacing gas, and the public won't make sacrifices continuing towards net zero (Temple, 2020).

The Transportation Fairness Alliance is an alliance supporting a "competitive and equitable transportation sector" funded by FTI Consulting and the American Petroleum Institute (TFA, 2021). Their concern stems from the conception that BEV's will cost the owner more, claiming that the "electric vehicle drivers contribute to road construction and maintenance costs, and... pay more than drivers of gas-power vehicles" (TFA 2021). The alliance hopes to dissuade vehicle owners from purchasing the BEV's due to the high TCO's. One of the members of the American Petroleum Institute, ExxonMobil, spearheaded a campaign against the electrification of automobiles. The Mobil 1 team, a motor oil sold by ExxonMobil, ad shows individuals attempting to move about their daily life while carrying cables with them. Mobil 1 stated that the commercial "makes visible the invisible threads that keep us all overconnected." The commercial aims to convince its viewers that EV's negatively impact their daily life. The commercial alludes to the American Dream of freedom, with the slogan: "Disconnecting. Feels a lot like breaking free. For the love of driving." (Mihalascu 2023).

Another coalition in support of EV's is the Zero Emissions Transportation Association, ZETA, which advocates for job creation, cleaner environment, and cost savings by transitioning to EV's. The Executive Director of ZETA, Albert Gore, claims that "ratifying the U.S.-Chile Tax

Treaty... is an important step in making the supply chain for clean technologies more resilient and more secure” (ZETA). Gore supports the expansion of business in the Lithium Triangle in order to support the mission towards EV’s. ZETA advocates for 100% EV sales; their second commitment is “enacting policies that drive EV adoption, create hundreds of thousands of jobs, secure American global EV manufacturing leadership, drastically improve public health, and significantly reduce carbon pollution.” (ZETA). Similarly, car companies like BMW, Ford, GM, Honda, Nissan, Subaru, and Volkswagen have all committed to EV’s making up at least 40 percent of their sales by 2030 (Rubio-Licht and Roach 2022). Both ZETA and the car manufacturers' stances are clear: advocate for EV production in order to avert the climate crisis.

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