Undergraduate Thesis Prospectus

Developing a Human-Powered Vehicle as a Practical Commuting Method

(technical research project in Mechanical Engineering)

Charlottesville's Plans for an Eco-Friendlier Transportation

(STS research project)

by

Sandesh Banskota

December 9, 2019

Technical Project Collaborators:
Students of MAE 4610-001 – Capstone Course

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: _____ date: 12/9/2019

approved: _____ date: Dec 9, 2019
Peter Norton, Department of Engineering and Society

approved: _____ date: 12/9/2019
Natasha L. Smith, Dept. of Mechanical & Aerospace Engineering

General research problem

How can transportation become eco-friendlier?

Modern transportation methods produce substantial environmental pollution and greenhouse gases. Over the past half-century, transportation has accounted for around 20% of the world's total CO_2 emissions and consequentially contributed to climate change (Ritchie & Roser, 2017). The sector has increased "the loss, isolation, and disturbance of wildlife habitat," which have reduced biodiversity and natural buffers against invasive species and floods (Litman, 1995).

While cities like Lyon, France are developing green transportation, many cities, such as Dallas, Texas, struggle to adopt such alternatives (Marsden et al., 2010). Globally, as developing countries become more affluent, more people will utilize existing environmentally unfriendly transportation methods, unless they invest in sustainable transportation systems. Although the long-term environmental, health, and economic benefits of a more sustainable transportation system are evident, the initial costs and required planning deter many cities and countries from pursuing an eco-friendly transportation system (Litman, 2012).

Developing a human-powered vehicle as a practical commuting method

How can human-powered vehicles be engineered to be practical for a typical commute?

This technical problem is part of a MAE Department capstone, advised by Professor Natasha Smith. Twelve peers and I will collaborate on design, experimentation, and answering this technical research problem.

Human-powered vehicles (HPVs) are vehicles "that are powered only by muscular-strength" (WHPVA, 2019). The human provides all the energy used for vehicle movement. Komanoff et al. (1993) concluded that HPVs have significantly lower environmental impact than

most other modes of transportation. He cited benefits such as 95 percent lower greenhouse gas emissions and reduction in water pollution, congestion, noise, and accidents. Developing a human-powered vehicle that is comparable, if not better than cars, in commute time, comfort, safety, cost, and effort will make HPVs an attractive option for many.

The goal of the project is to design a human-powered vehicle that exemplifies the integration of speed, safety, sustainability, durability, accessibility, and user-friendliness. Although human-powered boats and planes exist, the project will focus on land HPVs. This is largely due to time constraint and since most commuters do not have easy access to airspace or waterways.

Previous research on HPVs focused mainly on specific parts of the vehicles. Gross et al. (1983) published research on improving aerodynamics of HPVs, which would reduce aerodynamic drag on the HPV and reduce human effort required. Ambrož (2017) described inexpensive technology to build embedded, smarter HPVs. There are countless studies on maximizing power efficiency between the rider and the HPV (Capelli et al., 2008). Most publications are very narrow in scope; there are few research papers that look at HPVs holistically. This research project aims to design and manufacture an integrated, optimized HPV that would be an alternative to cars for commute.

This research project will take on three phases: (1) creating design objectives for HPV, (2) vehicle design and manufacturing, and (3) road testing. To develop general design objectives for the HPV, the team will survey the targeted customer base to quantify the importance of cost, comfort, safety, speed, and sustainability. Additionally, any comments and preferences on the survey will be analyzed. During the design process, the fairing, main frame, and drivetrain of the vehicle will be studied and optimized. Laboratory tests will be conducted on fairing material to

gather data on cost, strength, and weight. The team will optimize the shape of the fairing for aerodynamics under the constraints of the frame, and the frame based on experiments with the Biomechanics Laboratory at UVA and Finite Element Analysis. Drivetrain analysis will be completed to determine the effort required to pedal the vehicle. Ultimately, all integrated variations of the aforementioned parts will be tested against market preferences, and the project will propose and build an HPV prototype that is optimized for a typical commute.

Charlottesville's Plans for an Eco-Friendlier Transportation System

How are social groups in Charlottesville making the city's transportation system more sustainable?

Transportation is a major source of greenhouse gas emissions. According to the EPA (2019), transportation accounted for 29% of total U.S. greenhouse gas emissions in 2017. Such emissions are a major contributor to climate change and consequent sea-level rise and frequency of severe storms (Solomon et al., 2009). Charlottesville, Virginia is a small city of about 50,000 people (U.S. Census, 2018); about 1,200 cities in the U.S. are of similar size (U.S. Census, 2019). The city of Charlottesville is seeking to make its transportation greener, and its efforts may set an example for similar cities.

In a study of cities' sustainability efforts, Hikichi (2003) contends Charlottesville is taking a balanced approach, maintaining the current transportation system while planning for an eco-friendlier future. Santos et al. (2017) examined the use of sustainable pavements. Litman (2012) states that adding public transportation systems typically lead to a healthier population by encouraging walking, decreasing pollution, and reducing rate/severity of traffic accidents. In Germany, "regional land planning policies encourage compact, mixed-use development, and thus

keep trip distances short and feasible for walking or cycling" (Buehler et al., 2019). Sustainable technology, public transportation, and zoning laws are some methods that cities have utilized to make their transportation greener.

The Alliance for Community Choice in Transportation (ACCT), UVA Parking and Transportation, the Mid-Atlantic Transportation Sustainability University Transportation Center (MATS UTC), and the Virginia Department of Transportation Environmental Program (VDOT EP) are striving to influence the future of the city's transportation system.

ACCT is a local advocacy for green and safe transportation. It promotes "sustainable land use and transit-oriented communities through education and leadership" and advocates public investment in sustainable transportation (City of Charlottesville, 2010). It contends that greener transportation would be safer. The group also commissions studies on feasibility of eco-friendly transportation projects (McNair, 2005).

UVA Parking and Transportation (UVPT) plays a major role in the city since the University of Virginia's transportation system is intertwined with Charlottesville's. UVPT encourages alternatives by publicizing them to university employees and students (UVPT, 2009). To fulfill its goal of "reducing the University's transportation carbon footprint," the department has added more efficient buses to its fleet (Kelly, 2018). It is funded by the University of Virginia, which has its own agenda for reducing overall greenhouse gas emissions (Kelly, 2017). The university's Transportation Working Group (2019) promotes and explores sustainable modes of transportation.

MATS UTC is a coalition of universities headquartered in Charlottesville that researches methods to make transportation more sustainable in participating cities, including Charlottesville.

The group states that it aims “to accelerate adoption of sustainable practices in the provision of transportation services” in the region (MATS UTC, 2019).

The Virginia Department of Transportation Environmental Program (VDOT EP) funds green transportation projects that affect Charlottesville. The department claims it “works hard to balance environmental issues with transportation needs” (VDOT, 2019). For example, VDOT EP has investigated a more sustainable pavement material which would reduce greenhouse gas emissions (Santos et al., 2017).

References

Ambrož, M. (2017). Raspberry Pi as a low-cost data acquisition system for human powered vehicles. *Measurement*, 100, 7-18.

Buehler, R., Pucher, J., & Kunert, U. (2009). Making transportation sustainable: insights from Germany. Washington DC: Metropolitan Policy Program at Brookings.

Capelli, C., Ardigò, L. P., Schena, F., & Zamparo, P. (2008). Energy cost and mechanical efficiency of riding a human-powered recumbent bicycle. *Ergonomics*, 51(10), 1565-1575.

City of Charlottesville (2019). Sustainability in the Community. (n.d.). https://www.charlottesville.org/community/community-initiatives/a-green-city/sustainability-in-the-community.

EPA. (2019, Sep 13). U.S. Environmental Protection Agency. Sources of Greenhouse Gas Emissions. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

Gross, A. C., Kyle, C. R., & Malewicki, D. J. (1983). The aerodynamics of human-powered land vehicles. *Scientific American*, 249(6), 142-152.

Hikichi, L. (2003). New urbanism and transportation. *University of Wisconsin-Milwaukee*, 1-28.

Kelly, M. (2017, Apr 13). UVA to Announce Greenhouse Gas Action Plan During Upcoming Earth Week. *UVA Today.* https://news.virginia.edu/content/uva-announce-greenhouse-gas-action-plan-during-upcoming-earth-week.

Kelly, M. (2018, Oct 19). Alternative Transportation a Key Element of U.Va.'s Sustainability Efforts. *UVA Today.* https://news.virginia.edu/content/alternative-transportation-key-element-uvas-sustainability-efforts.

Komanoff, C., Roelofs, C., Orcutt, J., & Ketcham, B. (1993). Environmental benefits of bicycling and walking in the United States. *Transportation Research Record*, 1405, 7-7.

Litman, T. (1995). Land use impact costs of transportation. *World Transport Policy and Practice*, *1*(4), 9-16.

Litman, T. (2012). *Evaluating public transportation health benefits*. Victoria Transport Policy Institute.

Marsden, G., Frick, K. T., May, A. D., & Deakin, E. (2010). Transfer of Innovative Policies between Cities to Promote Sustainability: Case Study Evidence. *Transportation Research Record*, *2163*(1), 89–96.

MATS UTC. (2019, Dec 8). http://www.matsutc.org/.

McNair, D. (2005, Dec 1). Streetcar desire: Road rail our next big thing? *The Hook.* http://www.readthehook.com/98102/architecture-streetcar-desire-road-rail-our-next-big-thing.

Ritchie, H., & Roser, M. (2017). CO_2 and Greenhouse Gas Emissions. *Our World in Data*.

Solomon, S., Plattner, G. K., Knutti, R., & Friedlingstein, P. (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the national academy of sciences*, 106(6), 1704-1709.

Transportation Working Group. (2019, Oct 29). https://sustainability.virginia.edu/resources/transportation-working-group.

US Census Bureau. (2018). U.S. Census Bureau QuickFacts: Charlottesville city, Virginia (County). https://www.census.gov/quickfacts/charlottesvillecityvirginiacounty.

US Census Bureau. (May 31, 2019). Number of cities, towns and villages (incorporated places) in the United States in 2018, by population size [Graph]. *In Statista*. https://www.statista.com/statistics/241695/number-of-us-cities-towns-villages-by-population-size/

UVPT (2019). University of Virginia Parking and Transportation. Thriving Without a Car. (n.d.). https://parking.virginia.edu/thriving-without-car.

VDOT (n.d.). Virginia Department of Transportation. https://www.virginiadot.org/programs/pr-environmental.asp.

WHPVA. (n.d.). http://www.whpva.org/hpv.html.