Building a Three-Wheeled Recumbent Human Powered Vehicle for the American Society of Mechanical Engineers Competition
(Technical Topic)

How Transportation Inequality Affects Social Justice and Economic Inequality and the Effectiveness of Bikes
(STS Topic)

A Thesis Project 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

Matthew Evanko

Fall, 2019

Technical Project Team Members: Brian Lembo, Chris Wilks, Dana Poon, Geoff Shellady, Ian O'Donnell, Kevin Meyers, Nick Johnson, Pat Wongwiset, Richard Jiang, Samantha Davis, Sungwoo Cho, Thomas Lee

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 _____

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

Approved _____ Date _____
Natasha L. Smith, Associate Professor, Department of Mechanical & Aerospace Engineering

Introduction:

As we become more aware of our environmental impact through carbon emissions, biking has become an increasingly popular solution for transportation and exercise (Emamdjomeh 2010 n.p). Given the high price of cars, bikes can also be a great way for those in urban areas to get around when public transportation options fail, especially poorer people living in big cities. The American Society of Mechanical Engineers (ASME) competition to build a Human Powered Vehicle (HPV) aims to build a better bicycle or bike-alternative; one that can be fast but also that can endure long distance riding, while making way for obstacles that a rider could experience using it to go shopping, get to work, or just travel around their town. Biking in the real world is a controversial issue, however. Social justice issues include the ability of women to ride bicycles in countries with conservative and sexist religious traditions (Hadid 2016 n.p), and the inequality of transportation access for people with disabilities and along race or wealth gaps (Zaveri 2018 n.p).

As our public transportation systems fail, the inequality between those with and without adequate public or personal transportation is increasing (White 2015 n.p.). This trend leads to economic differences and an increase in the wealth gap between these groups. I will work with my team to design and build a three-wheeled HPV for the cost of a few thousand dollars, that will qualify and compete in the ASME competition, but that could also be used for travel in realistic contexts. I will also investigate the connection between transportation inequality with economic inequality, given the rise of bike sharing programs. I hope to look into how access to better transportation could increase social justice, with a focus on if HPVs are an appropriate solution to the problem. Due to the nature of competitions in developing technology, I want to acknowledge an actual social need for the technical aspect of my project.

Technical Topic: Building a Human Powered Vehicle

The ASME competition holds two different kinds of races that our HPV will have to complete to determine the value of our design. The first is a speed race, where the HPV must compete in what is essentially a drag race, on a straight, flat track. The second is an endurance race, where riders go through a longer course with stop signs, speed bumps, hills, and other obstacles. Our design must be able to deal with both races, while also having necessary safety features including a roll-over protection system (ASME 2019 n.p).

In making the human powered vehicle, our team had to face many design decisions that balanced our budget with our needs. These decisions include the number of wheels, the materials used in the frame, and the braking system. We used decision matrices to weigh these decisions, keeping in mind cost, our ability to manufacture them, and the weight benefit given that the HPV needs to be light enough to be transported to Georgia and powered by our team members. The biggest limiting factor our group faced was cost, as we have only $2000 to use, without considering outside fundraising. This often meant sacrificing performance or weight for cost, to be able to deliver any kind of complete vehicle within our time frame. For example, we chose for our fairing (the attachment on the front which increases aerodynamic efficiency) to use aluminum, rather than carbon fiber, due to the increased cost of carbon fiber and the possibility that any part will need to be adjusted or replaced if broken or incorrect. Some parts have sacrificed cost for efficiency, however, such as the seat, which is being ordered from a German craftsman to ensure it works properly, given that the last group to compete for UVA ended up with a broken seat before their competition.

Our group designed a frame in SolidWorks, shown in Figure 1, to be able to get a rough idea of our needs in manufacturing this kind of vehicle. Since we decided upon a three-wheeled vehicle, we then could create our CAD model around established ideas of design, such as having

a center of mass in the front half of the vehicle, to aid in the ease of calculations later on (Fenner 2010 n.p).

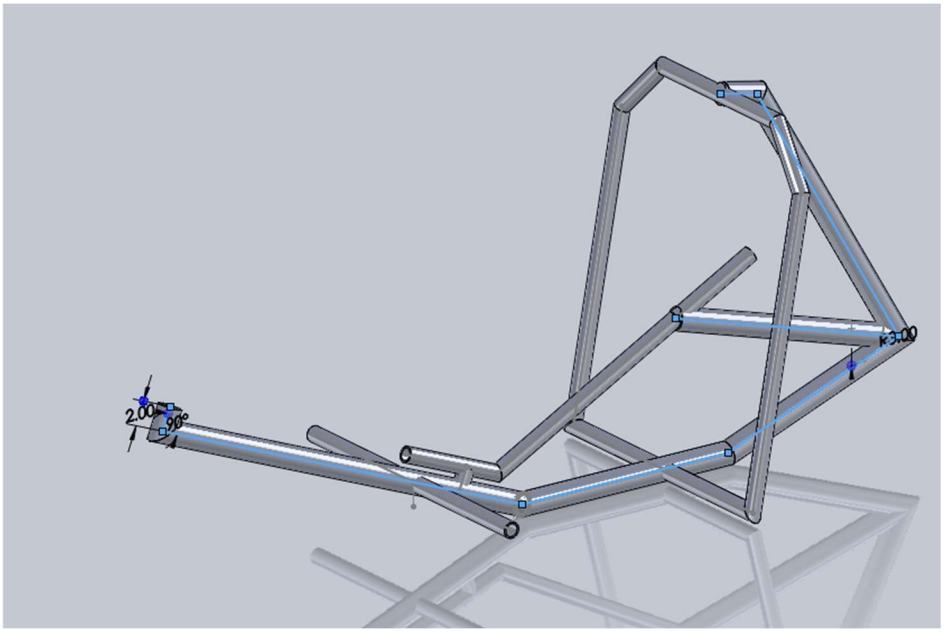

Figure 1: UVA HPVC Team SolidWorks Frame Design

A large part of our technical project is undergoing tests on the parts in order to determine what changes can be made to increase the efficiency of our vehicle. One of the ways we can do this is by utilizing the university's biomechanics lab to test how the angle of various leg sections changes the power output generated by pedaling. Making a wooden approximation of our frame enables us to test this without having the frame complete or risking the frame by exerting unnecessary stress. We will also be testing our weld strengths to ensure they are strong enough to connect the frame's rods and will test fairing types for aerodynamic efficiency.

The team will build upon the reports completed by past years' competitions, submitted by other university teams and accessed on the ASME website. We have read their design considerations, investigating both two and three-wheeled vehicles, as well as looking into all of the other variables relevant to the design. This mostly meant trying to identify the patterns of the

most successful past winners, with special attention given to ease of manufacturing due to our inexperience. Our deliverable is a 3-wheeled human powered vehicle, with under-seat steering, a tadpole configuration, and front-wheel braking. This vehicle will not be completed until well into the spring of 2020, in time for the ASME competition, but with sufficient room to make adjustments to the final product. To complete the project, our group will need to overcome our inexperience, researching how to make an efficient and sturdy bike, while also gaining hands on training with welding and construction.

STS Topic: The Effect of Transportation Inequality on Social Justice and Economic Inequality

Urban cities have long relied on public transportation for their populations to get around. New York City seems like the obvious example, given its buses, taxis, subway systems, and more. Given the dense population in big cities, public transportation becomes necessary to avoid congestion and allow people to get to work, markets, and to visit other people. However, in places that don't have such efficient systems, access to transportation can become a social justice issue, where those who cannot afford their own private transportation methods lose access to places they need to support themselves and their families. Some countries even have deep rooted cultural beliefs connected to transportation that resists change, and causes some groups to indiscriminately suffer.

Studies show that inequality in transportation leads to inequality in wealth, as poorer people who cannot afford to travel lose access to the premium jobs, food, schools, and goods that would enable them to lift themselves out of poverty (White 2015 n.p). Public transportation, especially buses, are aging and shut-downs are regular, leading to a lack of trust in the system and expensive renovations that would need to be done to return the system to being efficient and

usable . Human powered vehicles are a possible solution to this problem, but will need to be investigated to determine if they can be cost-effective, efficient, and culturally acceptable. Big-city governments especially must act quickly to address the need in their areas, to close the inequality between communities.

One relevant proposal to this issue is bike shares: placing bikes into neighborhoods and allowing users to access them for a fee, either a membership or an a per-ride basis. However, these ride shares show serious signs of discrimination. In Washington D.C., a survey showed that while the population was 50 percent black, ridership in bike-share programs was majority white, and more than half of users had annual incomes over $100,000 (White 2015 n.p). This leaves the poor people left behind by bike-sharing to stay in the broken public transit options. If bikesharing is to be an option to increase social equity, then companies would need incentives to push their programs into new communities actually in need. There would also need to be a change in the payment for these: bike-sharing systems and programs for scooter sharing such as Lime require either a smartphone to pay with, a credit card, or both, which severely limits the access to wealthier people who have already been able to afford those luxuries (Mhatre 2019 n.p). Bike-sharing also shows discrimination against those with disabilities, as standard twowheel bikes are inadequate for many with physical disabilities. A company in Detroit, MoGo, recently started a pilot program enabling those with limited mobility to use bike-shares. In this case, a man with cerebral palsy was able to ride a hand-powered tricycle that is being considered an “adaptive bike” aiming to reach those who cannot access normal bike-sharing (Zaveri 2018
n.p). In order to truly accommodate all people equally, new designs of bicycles and public transportation will need to be considered beyond this, such as those in wheelchairs or amputees.

As engineers, our group needs to consider the end result of our product, the user, and who we want to use our HPV.

Bike riding has socially relevant issues in other countries that in America we also might not consider. In Senegal, there has been resistance to modernizing transportation, either to bicycles or cars, given the country's strong tradition in riding horses with buggies (Hartocollis 2019 n.p). The president of the republic's logo is a horse, and people have long idolizing them as a part of the Senegalese culture. Meanwhile, in Gaza, women have been banned from riding bicycles, as they are considered too recreational and are related to sports. Gaza citizens have stated that "the role of our women is to obey their husbands and prepare food for them inside the house, not to imitate men and ride bikes in the streets" (Hadid 2016 n.p). However, women in Gaza are now raising their children with the concept of bike riding being a condition of marriage. Both of these examples show the necessity of cultural change as a part of making an HPV that can be used in the real world.

The problem of transportation inequality as it relates to bikes is a combination of all of the above issues. To address all of them at once would cast too large of a net, so I plan to focus on researching the effectiveness of bikes as a solution in American inner cities, and how transportation can increase equality for those in poverty and people with disabilities. Using that information, I could then analyze the UVA HPVC teams' designs in terms of how they address these issues, and then extending that to the ASME rules. Design competitions often suggest that technological development is inevitable, whereas an STS viewpoint demands that the social actors who use the technology dictate the rules of the competition to ensure ethical engineering design.

Conclusion

Our group will design and manufacture a three-wheeled human powered vehicle, that can be used in high-speed races while also being useable to traverse real world terrain. This design will include a roll-over protection system to ensure the safety of the rider, and will include our group's new skill in welding and other manufacturing skills. I will also be trying to gain a greater understanding in my STS work of how bike-sharing and other forms of public transportation can increase equality and act as an instrument of social justice to enable groups who have lost access to transportation, answering important questions: are people are open to bikes for transportation, are bikes affordable on a grand scale, and are competitions like ASME's aiding the development of technology that improves lives.

Our group's design addresses the concerns laid out in our design matrices by staying within our budget, but also will be able to travel stably at 5-8 km/hr and stop from 25 km/hr in 6 meters. The design also meets the ASME loading requirements, as well as the RPS requirement. My STS project will give a clearer understanding of how to address the problem of transportation inequality, and hopefully can inform how to better design a human powered vehicle so that it can realistically be applied to building up discriminated groups. In doing so, I hope to gain knowledge of the challenges faced in these communities, and how current systems are failing.

References

ASME (2019). Rules for the 2019 Human Powered Vehicle Challenge. https://community.asme.org/hpvc/m/default.aspx

Fenner, P. (2010). On the golden rule of trike design. www.deferredprocrastination.co.uk

Hartocollis, A. (2019). It's horses vs. motors in Senegal. The steeds still win on many roads. New York Times. https://www.nytimes.com/2019/09/10/world/africa/dakar-senegal-horsecarts.html?searchResultPosition=1

Mhatre, A. (2019). The great electric scooter backlash. CBS News. https://www.cbsnews.com/news/the-great-electric-scooter-backlash/

Hadid, D. and Al Waheidi, M. (2016). In Gaza, bicycles are a battleground for women who dare to ride. NY Times. https://www.nytimes.com/2016/02/23/world/middleeast/gaza-womenon-bikes-face-a-long-road-to-acceptance.html?searchResultPosition=9

Quinn, M. (2010). Urban bicycling: Is it becoming safer?
https://bayarea.blogs.nytimes.com/2010/02/19/urban-bicycling-is-it-becomingsafer/?searchResultPosition=1

New York Times Archives (1988). New headache on roads: drunken bicycling.
https://www.nytimes.com/1988/01/05/us/new-headache-on-roads-drunkenbicycling.html?searchResultPosition=9

Emamdjomeh, A. (2010). Bike lanes and other things bike to proliferate in Bay Area cities. NY Times. https://bayarea.blogs.nytimes.com/2010/01/07/bike-lanes-to-proliferate-in-bayarea-cities/?searchResultPosition=4

White, G. (2015). Stranded: How America's failing public transportation increases inequality. https://www.theatlantic.com/business/archive/2015/05/stranded-how-americas-failingpublic-transportation-increases-inequality/393419/

Zaveri, M. (2018). Bike-share options are rarely available for people with disabilities. NY Times. https://www.nytimes.com/2018/12/10/us/bike-share-disabilitiesdetroit.html?searchResultPosition=25