Designing a Human Powered Vehicle for Urban Environments

(Technical Paper)

Analyzing Greenhouse Gas Emissions from Transportation Methods in Large Cities

(STS Paper)

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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: The Carbon Footprints of an Individual

How can people be aware of and encouraged to reduce their personal carbon footprint on a day-to-day basis?

Now more than ever, it is increasingly important to be aware of your own carbon footprint. A carbon footprint is the amount of carbon released into the air by a certain activity. The US has the second largest carbon footprint in the world, making up 15.6% of the world's share of carbon emissions (*Climate Change & the Carbon Footprint*, n.d.). In 2005, the average US household had a carbon footprint of 48 tons per year (Jones & Kammen, 2011). More often than not, people don't think about how much they personally contribute to climate change. Many people have the mentality of "I'm only one person, changing my actions won't make a difference". However, if a collective society of individuals think like this, the results can be drastic. In the US, large cities such as New York, Los Angeles, Chicago, and Boston rank among the highest in carbon emissions for a clustered region. Even per capita, cities like Los Angeles and New York still rank in the top (Moran et al., 2018). Many of these large cities often draw workers because of their benefits: great restaurants, parks, museums, and shops. However, getting around – particularly to and from work – is often a challenge in these large but crowded environments. Many big cities have systems of public transit in place, including trains, subways, and trolleys. Most modern subway and train systems are powered off of electricity, so on the surface it may seem like a much better alternative to driving a car. However, it is important to note where that electricity comes from. In 2017, a combined 64% of electricity generated in the US was from natural gas and coal power plants (Muyskens et al., 2017). So often times, taking a subway or train to work can still have a significant environmental impact. This will be discussed in more detail in the thesis. Additionally, subway systems are often cramped, unmaintained, and unreliable. In New York City, from 1991 to 2017,

subway on-time performance steadily declined until it hit a low of a 26% decrease (Rosenthal et al., 2017). In many cities, unreliable and neglected public transit systems often leads more people to drive their own car or take a bus to work. In 2017, 41% of commuters in New York City used a means of transportation that emitted greenhouse gases. This included cars, vans, trucks, buses, and taxicabs (United States Census Bureau, 2020). Governors, mayors, and other policymakers are partly at fault for this. Many cities are not "biker-friendly", where it is inconvenient or unsafe to bike to work. If more cities could develop infrastructure such as fast bike lanes and roads, this may encourage less people to use carbon-emitting transportation. These policies will also be looked at in more detail in the final thesis. My capstone team aims to develop a better commuter human powered vehicle for use in these cities. This is strongly coupled to my thesis research, of analyzing the effects of incorporating more bicycle travel into a commuter's day.

Design of a Practical Human Powered Vehicle for Urban Environments

How can the commuter bicycle be re-designed so as to become a more popular mode of city transportation?

Bicycles can be a great alternate mode of transportation. They are particularly great for traveling distances quickly, like from one side of a city to another. They emit zero carbon emissions, and are a great way to stay active in today's somewhat sedentary society. However, just over 1% of New York City commuters regularly biked to work in 2017 (United States Census Bureau, 2020). Despite their perks, commuter bikes are not perfect. The generic design of them has not changed in decades, and many aspects of it remain unfit for city travel. Bikes are often unsafe, especially when riding next to and with automobiles. There is virtually nothing to protect the rider's body from external forces of a crash or impact. In 2018, there were 857 deaths of bikers due to an automobile crash (NHTSA, n.d.). Significantly more non-fatal cycling accidents occur,

and many have the impression of biking being much more dangerous. Additionally, biking for extended periods of time can be uncomfortable and exhausting. Most standard bicycles do not have large seats, and require a forward bending position to operate correctly. A fair amount of effort must be put into balancing the bike as well. This is particularly challenging when there are frequent stops, such as in a city environment with many intersections. With the exception of a front basket or secured back rack, most bicycles don't have any forms of storage for the rider. This is particularly inconvenient when biking is a commuter's primary mode of transportation. Simple tasks like going to the grocery store can become very difficult.

My capstone team aims to design a much more practical human powered vehicle, that addresses all of the previously outlined problems. This vehicle will be intended to replace the commuter bicycle in cities, and be a reasonable alternative to other forms of transportation like driving and subways. To begin, we have looked at past years' submissions to the ASME Human Powered Vehicle Challenge. Many of these submissions provide valuable insight to the challenges of designing a vehicle as described. Looking through prior designs helped us pick a three-wheeled, recumbent shape with a roll cage to start with. Additionally, the competition rules provided by ASME give some general guidelines of where to start in terms of the parameters of the vehicle. Things like the minimum compressive strength of the vehicle roll cage, minimum braking distance, and minimum turning radius are provided in the rules. These parameters were where we started with the design. Using SolidWorks, we have developed a comprehensive model that includes the frame design, steering system, and an adjustable seat (Figure 1). Other aspects of the design, such as the braking system, bearings used, and chain/derailleur setup are soon to be implemented into the model. Finite element analysis (FEA) has been used in order to optimize the size of our frame. Based on roll cage requirements given by the competition rules, we incorporated an iterative

process that allowed us to minimize weight while maximizing strength. This helped us come to our final pipe and channel thickness of the frame. In the next part of the simulations, we will be conducting computational fluid dynamics (CFD) to optimize the design of a wind fairing. This fairing will help increase efficiency with its aerodynamics, as well as provide some external protection from the elements for the rider. Next semester, we plan to begin fabrication of a prototype in Lacy Hall. Throughout this process, we will be conducting testing on the vehicle, and adapting as needed.

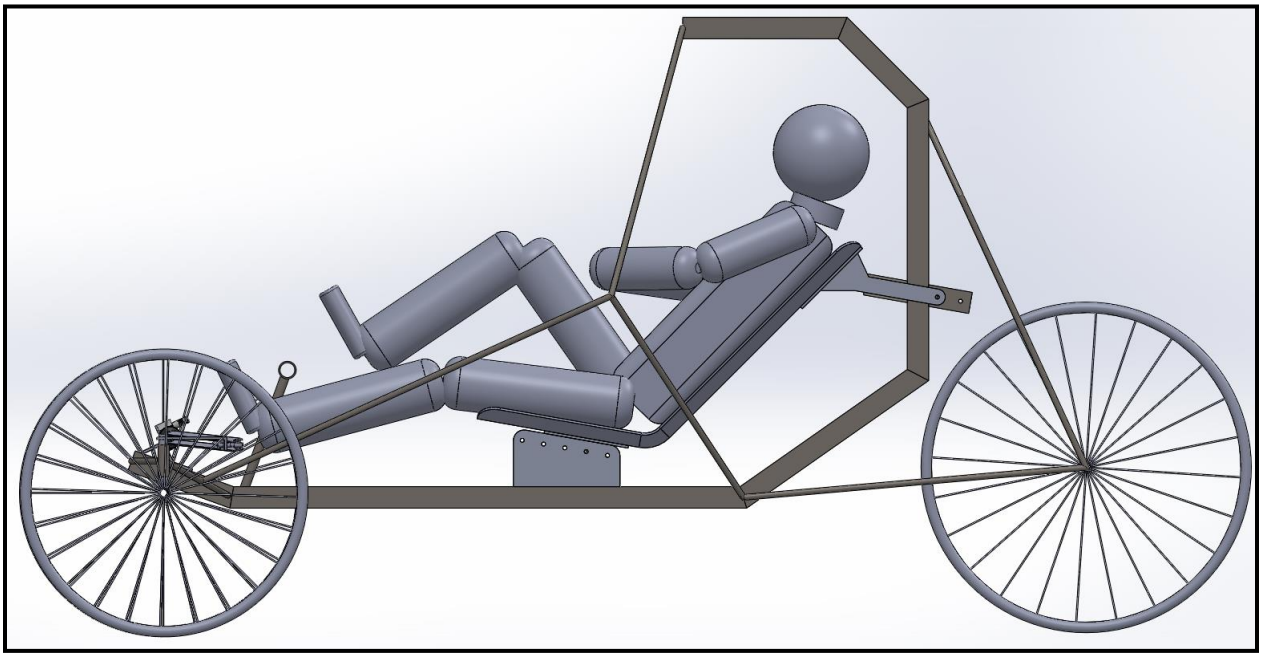

Figure 1. Side view of human powered vehicle in SolidWorks

One particularly limiting portion of this project is the unavailability of welding training. Our small team of seven has had trouble getting welding training and practice from Lacy Hall, due to a back-log of COVID-19 related delays. We still plan to be proficient enough to build a prototype by February. This project will be a culmination of many of our engineering skilled that we have learned over the past four years. We hope that our prototype shows to be a viable

replacement of greenhouse gas-emitting vehicles. In the future, streamlining the manufacturing process would be something of interest and another avenue of research.

Analyzing Greenhouse Gas Emission from Large Cities

What effects would reducing greenhouse gas emissions from city commuters have on the environment?

Most educated people would agree that climate change is one of the largest problems facing human-kind to date. The way that modern society lives can be seen as a detriment to the Earth. Pollution, excessive use of electricity, deliveries, transportation; the list goes on. All things that used to be non-existent some 150 years ago, and now are a major result of today's culture. But what are the consequences of all this? Are single-degree differences in global temperatures a big deal? Will meters in sea level change over decades effect our coastal cities? Are hurricanes becoming more devastating, particularly for low-income communities? The answers to all of these questions are a function of what changes individuals and lawmakers make over the next couple of decades. Generally, my thesis will look into the currently predicted effects of climate change, and how changes in society's actions can change those predictions. Specifically, research on the effects of decreasing carbon emissions of city-commuters will be done.

The Intergovernmental Panel on Climate Change (IPCC) stated in 2015 that "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history." (IPCC, 2015, p. 2). There is no doubt that current society has a significant effect on climate change as a whole. Particularly since the industrial revolution in the early 1800s, humans have significantly increased their carbon footprint. In the US, the transportation sector accounts for the largest portion of greenhouse gas emission, at 28% (EPA,

2018). This includes trains, buses, cars, and trucks. As looked at earlier, large cities account for much of the transportation carbon footprint, even per capita. There exists much data to support both the idea of climate change, as well as transportation and climate change. The IPCC, for one, is a body of the United Nations that assesses the science, causes, and effects of climate change on the planet. They provide data and suggestions on the best courses of action for policy makers around the globe. Additionally, they release comprehensive reports of the current state of climate change, and predictions about the future. NASA and the Goddard Institute for Space Studies (GISS) provide satellite data on things like air temperatures, sea level, carbon dioxide levels, and ozone levels. All of these sources will be used to assess the current state of the climate, as well as make predictions about the future, given certain changes or the lack thereof. The US Census Bureau releases data on transportation statistics of commuters in different cities. This, in combination with data about emissions from different types of commuting methods, will be useful in predicting trends.

By the end of the year, I would like to be able to show the effect that an increase in human powered vehicles in large cities will have on climate change as a whole. The consequences that climate change will have on communities around the globe will also be a derivative of that result. These will both be significant, as it will show how relevant to society my technical project is.

Research Methods

Firstly, I plan to gather greenhouse gas emission data over the last decade or two. Specifically, I will look at how data from large cities compares to data from the US as a whole. I then plan to do an even greater analysis of one individual city, such as New York City, to use as a model for the average large city in the US. I will also look at how this data trends and what experts are predicting for the future. Next, I will look at the breakdown of transportation methods; In the

US as a whole, large cities as a whole, and New York City. I will be particularly interested in commuters, i.e. people who travel a relatively short distance to work on a daily basis. This is because my technical project revolves around redesigning the commuter bicycle. This transportation data will be used in conjunction with greenhouse gas emission data. They will help to interpret what might be predicted if much of the transportation sectors of large cities were primarily using human powered vehicles instead of cars, buses, etc. This will be a key result, as it will tightly couple with my technical project. Finally, I will analyze the environmental and societal effects of climate change over the next few decades, both with and without the widespread use of human powered vehicles in large cities.

Conclusion

Climate change will likely affect everyone on the planet in some way or another. Creating a society where it is encouraged to think about your carbon footprint and the consequences of your daily actions is likely going to be a key tool in combatting this issue. The consequences of climate change are becoming more and more drastic. Analyzing the effects of human powered vehicles as a primary mode of transportation in cities will hopefully show that even small changes to everyday lifestyle can have large impacts, when done as a whole.

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Figure 1 was created entirely by the author.