Investigating the Effects on Climate Change of Making Large Cities More Cyclist-Friendly

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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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Introduction

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). It is abundantly apparent that climate change is the principal issue facing the present generation. However, more often than not people do not think about how much they contribute to climate change. Many people have the mentality of "I'm only one person, changing my actions won't make a difference". The problems start when everyone has that mentality.

It would be unrealistic to assume that every individual would be capable of directly aiding the efforts of combatting climate change. However, there are small steps that many people can take on a daily basis that could prove effective in reducing the impact that climate change has on the world in the coming decades. This research paper will look into how climate change will be affected if percentages of commuters in US cities switch to biking as their primary mode of daily transportation. Particularly, it will compare the carbon emissions of various modes of city transportation, and the effect these emissions will have on climate change over the coming decades.

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 sedentary society. That being said, many commuters stay away from them, as they are often unsafe, uncomfortable, and impractical. My capstone team designed and manufactured a much more practical human powered vehicle that would exist to replace the modern bicycle in large cities. This vehicle aims to be safer, more comfortable, easier to ride, and more practical than traditional bicycles. It was originally designed to compete in the ASME Human Powered Vehicle challenge, but has been modified to act as an ideal commuter vehicle. The vehicle has a three-wheeled recumbent design, which is optimized for strength and weight. It uses an internal hub, which allows for easy gear changing even when stopped at a light. It contains a storage compartment, which makes for trips to a grocery store much more convenient. The design process was iterative, and tools like SolidWorks Finite Element Analysis (FEA) were used to test the strength of the design. See Figure 1 for a rendering.

Figure 1. Rendering of technical project human powered vehicle

Carbon Emissions in the US

A carbon footprint is the amount of carbon gas released into the air by an activity. Globally, carbon emissions have increased over 370% since just 1960 (US EPA, 2016). In 2020, the US had the second largest carbon footprint in the world, making up 15% of total global carbon emissions.

Additionally, in 2018 the US ranked fourth for most carbon emissions per capita (*Each Country's Share of CO2 Emissions*, 2020). It is clear that the US is a primary contributor of greenhouse gas emissions, and has been for a long time as well. A variety of researchers from various oil companies in the US was fully aware of the consequences of their companies' air pollution, as early as 1960. It took years for companies to actually begin initiatives aimed at reducing their carbon emissions, and it was never a priority over profits (Hasemyer et al., 2016).

Large cities, or "clustered regions," typically contribute significant portions to a country's total carbon footprint. One hundred cities worldwide generate 18% of all global carbon emissions. As one might expect, US cities like New York, Los Angeles, and Chicago produce the most carbon emissions in the country. In 2018, they produced 234, 196, and 153 million metric tons of CO2 (Mt CO2), respectively. In addition to other cities like New Orleans, Detroit, and Cleveland, the above-mentioned three still rank high per capita (Moran et al., 2018). This paper will focus its research specifically on New York City, whose cluster population as defined by Moran et al. is approximately 13 million.

Transportation in New York City

In the US, the transportation sector makes of 28% of the total greenhouse gas emissions. This is the highest of any sector, closely followed by power generation at 27% (US EPA, 2015). Transportation emissions include that from cars, trucks, ships, planes, and trains. Power generation or electricity emissions includes that coming from burning fossil fuels, such as coal and natural gas, which makes up about 63% of US electricity generation (*Electricity in the U.S.*, 2021). Clearly, there is significant room for improvement in both of these sectors. In 2017, of all approximately 4.8 million people commuting to work in NYC, 41% used a means of transportation that emitted greenhouse gases. This included cars, vans, trucks, buses, and taxis. About 9% walked, and only 1% rode a bicycle. The majority of the remainder used either subways or railroads, at approximately 48% (United States Census Bureau, 2020).

So why are so few New York City commuters walking or biking? Part of the blame can be put on mayors and local leaders. Bike lanes are broken up in to class I, class II, and class III lanes. Class I lanes, the safest, are physically separated from the adjacent road, usually by parked cars or concrete barriers. Class II lanes are directly adjacent to the road, and signified only by painted markings. Class III lanes are where the bike lane is shared with a slightly wider road (*Bike Lanes in NYC*, 2013). Despite the almost 100 miles of class I bike lanes constructed in NYC since 2014, safety problems remain. In 2019, there were 25 bicycle deaths in NYC, a record high (Fitzsimmons, 2019). Especially because of the (quite accurate) reputation NY, drivers have of being rather reckless; many people are deterred away from cycling, amongst other safety concerns.

Resulting Greenhouse Gas Emission of the NYC Metro System

Some might see the 48% of New Yorkers using subways and railroads as a good thing. However, these systems are almost entirely powered from electricity, and it is important to be aware of where that electricity comes from. By analyzing the average power drawn by similar metro systems in other cities, we can interpolate how much power is drawn by NYC metro, and the resulting impact on greenhouse gas emissions. New York City represents almost 60% of New York State's power consumption yearly. Additionally, most of that power is coming from natural gas power plants, throughout upstate New York and New Jersey (Rueb, n.d.). In 2017, Beijing's metro network consisted of 367 miles of rail tracks, and in prior year consumed a total of 1.71 billion kWh of energy (Yu et al., 2020). On average, this equates to 4.65 million kWh of yearly consumption per mile of rail track. According to the Metropolitan Transportation Association (MTA), in 2017 the New York City subway system had 665 mainline miles of track (*Facts and*

Figures, n.d.). Assuming the same ratio that means the NYC metro system consumed approximately 3 billion kWh of energy in 2017. We can assume that 80% of NYC's energy comes from natural gas plants (the other 20% is a mix of nuclear and renewables). Natural gas plants emit an average of 549 g of carbon dioxide per every kWh (Proctor, 2014). Thus, it can be approximated that transportation via subway and railroads in New York City was cause for 1.7 Mt CO2 emissions per year.

Resulting Greenhouse Gas Emission of Cars, Truck, and Cabs

The 41% of New Yorkers who traveled to work using cars, trucks, and cabs shows how much room for improvement there is on this front. The average passenger vehicle emits approximately 400 g of CO2 per mile driven (US EPA, 2016) However, the actual emitted CO2 is usually quite higher in a city, due to the time spent sitting in traffic or at stoplights. We can adjust this number based on the mile per gallon (mpg) rating of cars. A typically city to highway mpg rating could be 19 to 25. We can use this and multiply 400 by 1.25 to get approximately 500 g of CO2 emitted per mile driven in New York City. The 41% using cars, trucks, and cabs represents approximately 1.9 million drivers. An average commute across the length of the city (e.g. Bronx to lower Manhattan) could be around 15 miles. Doubling this for return trips, and assuming work 5 days a week for 50 weeks in a year, gives us 7.1 Mt CO2 per year.

Transforming City Transportation Networks

In 2019, Mayor Bill de Blasio announced a plan to develop 250 miles of class I bike lanes in the coming years. This would almost triple the present 126 miles of class I bike lanes, and add to the present 1250 miles of class II and III bike lanes (Fitzsimmons, 2019). Suppose that this, and the development of vehicles like that described by my technical project, helped to encourage people to use cars and subways less. If more people began to feel safer biking to work, less people would be driving on the road, and this could potentially snowball to further increase the number of those biking. To start, let us assume that 10% percent of those using cars decided to sell their vehicle and commit to getting to work in other ways. Suppose this portion of commuters decided to bike to work 80% of the time, and take the subway the other 20% of the time. This can be represented by riding the subway 1 day a week. Let us assume that every year this portion of people giving up their car grew by 110%. Figure 2 shows the effect of this hypothetical scenario on transportation emissions in NYC over a 7-year period.

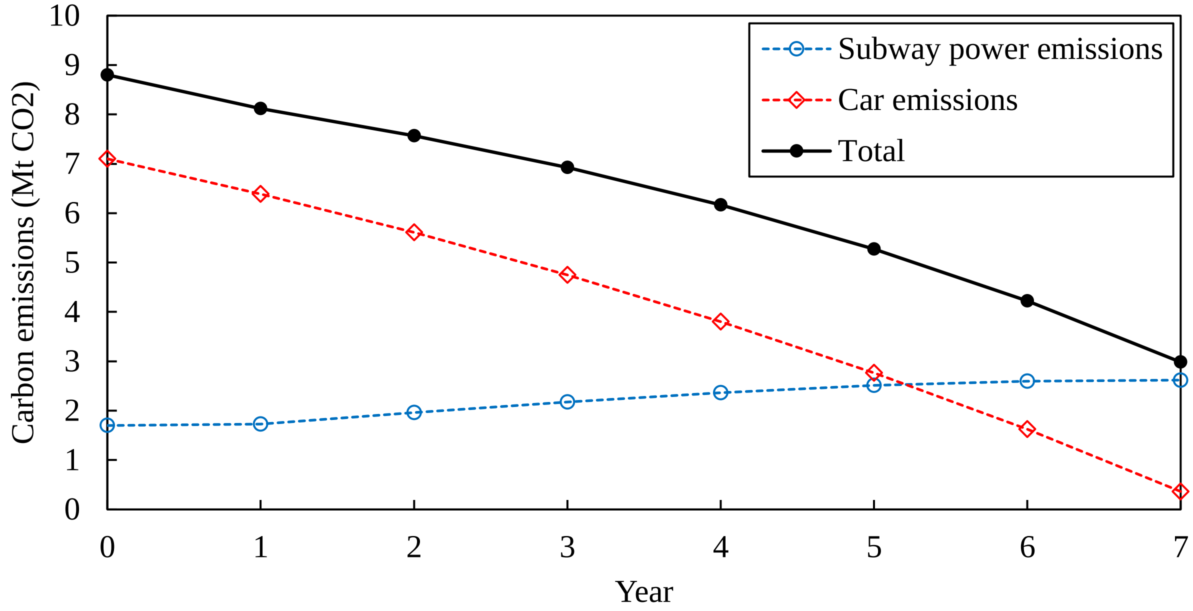

Figure 2. Projected NYC transportation emissions over a 7-year period.

It is important to note that this is a very hypothetical scenario described. Assuming bikers use the subway 1 day a week, and that bikers grow by 110%, are arbitrary assumptions made from common sense. Changing these would in turn change the results. However, they are relatively conservative assumptions, so what this does show is that a significant reduce in greenhouse gases from the transportation sector of large cities is very achievable over the next decade. With the present assumptions, this demonstration shows a 66% (5.8 Mt CO2) reduction in transportation greenhouse gas emission, in just 7 years. Other factors, such as the growing prominence of electric cars, and increased reliance on renewable energy, could help reduce this even more.

This 5.8 Mt CO2 reduction may not seem significant, especially compared to the 234 Mt CO2 that New York City produces yearly. However, over the years this adds up. Particularly as other sectors such as energy and industry begin to work towards a smaller carbon footprint, 5.8 Mt CO2 will become a larger and larger proportion of NYC's footprint. Additionally, infrastructure changes meant to make cities more bike-friendly can be applied to other clusters nationwide. If we assume the same reduction in carbon emissions per capita, we can interpolate NYC's result to other major cities in the US. Consider Table 1, which lists the US's top cities in carbon emissions.

Table 1. Carbon emissions and projected reductions of selected US cities

City	NY	LA	Chicago	Miami	Dallas	Detroit	Philly	Houston	DC	Total
Population (million)	13.6	13.5	7.3	5.0	4.7	2.8	3.6	4.5	3.3	58.3
Emissions (Mt CO2/yr)	234	196	153	80	77	71	70	66	62	1009
Projected change in emissions (Mt CO2/yr)	5.8	5.7	3.1	2.1	2.0	1.2	1.5	1.9	1.4	24.5
Percent reduction	2.5%	2.9%	2.0%	2.7%	2.6%	1.7%	2.2%	2.9%	2.3%	2.4%

Once again, it is important to note that these are only projections. It is likely that cities with different forms of transportation and different present bike infrastructure would lead to different results. However, averaged over the nine cities, we can get an idea of how effective these reductions would be.

Effect of Reduced Greenhouse Gas Emission

The Paris Climate Agreement of 2015 meant that all signing countries would work to limit the global temperature rise to at most 2°C, ideally 1.5°C (USGCRP, n.d.). If this were not achieved, the consequences would be irreversible and drastic. Representative Concentration Pathways (RCPs) are scenarios or paths that the globe can possibly take over the next several decades, dependent on what changes the world makes. These projections are based on the change in radiative forcing on the tropopause by 2100, relative to pre-industry levels. The different projections are labeled by their fluxes (e.g., RCP4.5 represents the path we would take if the change in radiative forcing on the troposphere by 2100 relative to pre-industry levels changed by +4.5 watts per square meter). Different RCPs allow us to see what will change in our atmosphere depending on what action we take/do not take. The best scenario, RCP2.6, projects that by 2040 global carbon emissions will be down from 10 to 5 billion metric tons of CO2 (Gt CO2) per year. RCP4.5 continues to climb until 2040, RCP6.0 until 2080, and RCP8.5 increases until and throughout 2100. RCP2.6 would represent at global temperature increase of only ~1.6°C by 2100, while RCP4.5, and RCP8.5 represent 3.5°C and 8.0°C increase, respectively (USGCRP, n.d.). NASA, a leading organization in climate change data acquisition, outlines some of the severe effects of climate change, which will only be worse the hotter the Earth gets. Some of these include increased "frost-free" season, which will dramatically change the agricultural industry, increases in devastating hurricanes throughout the world, and increases in droughts and heat waves. Additionally, the sea level will rise significantly (at worst, 8ft+) by 2100. This will displace entire cities like Miami and parts of New York, which will have dire consequences for those living there (Jackson, n.d.).

Conclusion

The reductions in emissions outlined by Table 1 shows, on average, approximately a 2% decrease because of the given scenario. Being that this is just a result of the transportation sectors in large cities making mild changes, this can be concluded as significant. If just a proportion of commuters in cities throughout the globe committed to cycling to work every year, we could see significant effects on the world's carbon emissions. Among other efforts, this could help to ensure that we match the RCP2.6 path, and keep the global temperature rise below 2°C. Government leaders and mayors of cities can help this effort by introducing more bike-friendly infrastructure, and finding ways to increase the efficiency of their transit systems. The development of more convenient human powered vehicles like that of my technical project would help to increase the popularity of city biking, and aid carbon emission efforts further. If I were to continue this research, I would look past transportation of large cities. Small cities, or suburban communities, and their respective effects on carbon emissions would be of great interest. Looking into how these smaller communities could transform their way of life as to reduce carbon emissions would be a great next step.

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