One small change in the way we travel, one giant leap for the environment[1]

The (Green)Power Rangers

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Overview

[1] Words inspired by Neil Armstrong. “One small step for man one giant leap for mankind”.

The (Green) Power Rangers aims to inform the general public on how much people contribute to climate change through CO2 emissions from transportation. Climate change is a very popular and serious problem. However, there are many people that do not know what it really means or how their day-to-day life can contribute to the issue. According to NASA, "climate change is a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates. These changes are primarily driven by human activities, particularly fossil fuel burning." This is not only a science issue, but also a social issue because the environmental and health consequences of climate change, which disproportionately affect low-income countries and poor people in high-income countries, profoundly affect human rights and social justice. Climate change will affect agricultural production, access to safe water, and worker productivity, and, by inundating land or making land uninhabitable and uncultivable, will force many people to become environmental refugees. Therefore, this is a very important issue for us, because we believe that if we can help people learn the consequences of their actions we can help eliminate the problem. This is also crucial for our target audience, because they can learn the consequences of their specific actions in transportation. To illustrate, via our project, viewers can learn how much CO2 emissions their average daily commute produces and how environmentally friendly the alternative types of transportation are. Lastly, viewers will also learn how CO2 emissions change over the years globally or in specific countries.

Data

We used a total of four datasets, three of which are from Our World In Data (OWID), which is a reliable open to public website that is used by many research and media institutions and universities, and Statista, which is a well known and reliable data source. Climate Change & CO2 101 section uses a dataset of *CO2 emissions by sector in 2016*, which provides the share of CO2 emissions (%) contributed by 25 sub-sectors. Next, the Unsustainable CO2 Emissions section uses the complete *CO2 and Greenhouse Gas Emissions* dataset by OWID that has over 23,000 observations and 55 vectors covering the years of 1900 to 2020 for many countries. Moreover, we also use the Worldwide *Automobile Production* dataset by Statista covering the years of 2000 to 2020 in this section. In the remaining sections, we use *Carbon Footprint Travel Mode* dataset by OWID that provides the amount of CO2 emissions per km for over 30 different modes of transportation to calculate how much emissions the user contributes with respect to their input.

Analytical Questions

We aim to answer the following questions in Section 1:

- What is the share of CO2 emissions from transportation compared to other sectors?
- What are the shares of CO2 emissions from different types of transportation?

We aim to answer the following questions in Section 2:

- How does global annual and cumulative CO2 emissions change over time?
- How does annual and cumulative CO2 emissions change over time for the chosen country?
- How does annual and cumulative vehicle (car) production change since 2000?

We aim to answer the following questions in Section 3:

- How much CO2 emissions does the user produce from their daily average commute depending on the distance of the travel and the mode of transportation?
- How much CO2 emissions does one produce over the next 5 years by different means of transport?

We aim to answer the following questions in Section 4:

- How many people taking/driving the chosen types of vehicles would produce the same amount of CO2 emissions to another selected type of vehicle operating by 1 person?

We aim to answer the following questions in Section 5:

- How will CO2 emissions trend change in the next 10 years if more people switch to environmentally friendly methods of transportation?

Visualization

In "Climate Change & CO2 101", we define climate change to ensure that all viewers understand the topic, since our target audience is the general public. Because our project focuses on CO2 emissions from transportation, we use interactive pie charts to demonstrate the share of total global CO2 emissions produced from transportation and the proportions of emissions from different transportation types. Figure 1.1, displays

the proportion of total global CO2 emissions from transportation and others in 2016. Because we want to focus on transportation, we decided to merge all other sectors into the 'Other' category to avoid overwhelming the viewer. When they hover over the pie, they can see the exact percentage of CO2 emissions, which we hope that this feature overcomes the perception limitation of using area as a channel. The two colors are also very distinctive and color blind safe. Similarly, in figure 1.2, the viewer can use the same interaction feature to see the percentages of contribution of types of transportation to total CO2 emissions from transportation. The colours of this pie chart is also easy to discriminate. Next, we narrow our focus onto the biggest contributor of emissions from transportation: cars. To help viewers understand the size of the large numbers for total CO2 emissions given, we provide a comparison of how many trees work to reduce the CO2 from the atmosphere. Lastly, we provide the exact amount of CO2 emissions from transportation in 2016, however such a large number is difficult to perceive. Thus, we use the Amazon rainforest as a comparison to show how many trees would be needed to absorb all CO2 from transportation by using our previously found ratio. However, one limitation is that this figure might be misleading, as we are not comparing this to any other visual, we are depending on the map's accuracy of showing the size of continents. As we discussed in class, the curvature might change the perception. Lastly, another limitation is that our data is only for 2016. We could not find more recent data, however since we know CO2 emissions and car production have increasing trends over the years, it is safe to assume that the proportion of CO2 emissions did not decline.

Majority of the designs proposed in the Mock-Up for "Unsustainable CO2 Emissions" were implemented. The goal is to highlight two important points namely, that CO2 emissions are following an increasing trend and that there appears to be a correlation between CO2 emissions and car production. We felt that this section is crucial because it shows the user that the situation is not improving which we hope would help with persuading them to consider greener alternatives as a means of travel in the following sections. The line plots shown in this section are interactive, with radio buttons allowing the user to select different views. The default selection shows both total CO2 emissions and CO2 emissions from gas production annually over all years where data was collected and vehicle production data. Cumulative data is also provided for the user to examine. Data from gas production was used as it was the most relevant to the project. CO2 emissions data coming from transportation was the initial choice but the data was not available in the dataset. The user is also able to view data from individual countries using the selection box and also change the time period using the slider buttons. These interactions were included to invite the user to explore the data further. The line plot on the left shows the CO2 emission for a chosen view on the y-axis, against a chosen time period on the x-axis. The line plot on the right shows the total number of cars produced on the y-axis against a chosen time period on the x-axis. Further, a red highlight was included for two major events that appeared to have an impact on the trend namely the Global Financial Crisis of 2008 and the current COVID-19 pandemic. As can be seen in the plots, both these time periods experienced a reduction in both CO2 emissions and Vehicle Production further indicating a possible correlation between the data. The position on common scale magnitude channels with line marks were chosen for the plots as they are highly effective at representing the data. Another design considered was a bar chart, however we felt that it would be less effective at communicating our main points and potentially cause the visualization to be too cluttered. One limitation with this design is that it is highly dependent on the data. For instance, data since 1751 was available for CO2 emissions for all countries, however, vehicle production data was limited.

In "What's your 'contribution'?", we conduct a survey on what type of vehicle people use in their daily life and how far they will commute every day on average to see the level of Co2 emissions the audience releases. There is a slider bar which can be used to select the distance and there are several radio buttons to denote multiple choices of various types of vehicle in this second question of the survey. You can only make one choice in this part, since we want to see the Co2 emissions related to the primary vehicles you use in your daily life.

Based on the CO2 emissions per passenger per kilometer data, we can easily calculate the CO2 emission level they release by multiplying the CO2 emission of various vehicles per kilometer by the distance the audience input. The total amount of CO2 emissions you release will also be displayed at the bottom of the survey. You can change the choices of primary vehicles and the distance and the result of total CO2 emission will also be changed.

The result will also be reflected on the interactive visualization. There is a graph with several chimneys at the bottom of the survey. And there is smoke with different color hues which are red from the darkest to the lightest to stand for different levels of the CO2 emission levels from the highest to the lowest. This is an interactive visualization. If CO2 emissions are less than 2500g, then it corresponds to extremely low level; if CO2 emissions are greater than 2500g and less than 5000g, which means low level; for CO2 greater than 5000g and less than 7500g, the level will be medium; if the results are greater than 7500g and less than 10000g, it will denote high level; finally, if CO2 emissions are greater than 10000g, the result will be regarded as extremely high level of emissions. If you change the choices, the result will be changed by calculations. These changes will reflect on the visualizations. There are two examples of the survey part – Figure 3.1 and Figure 3.2:

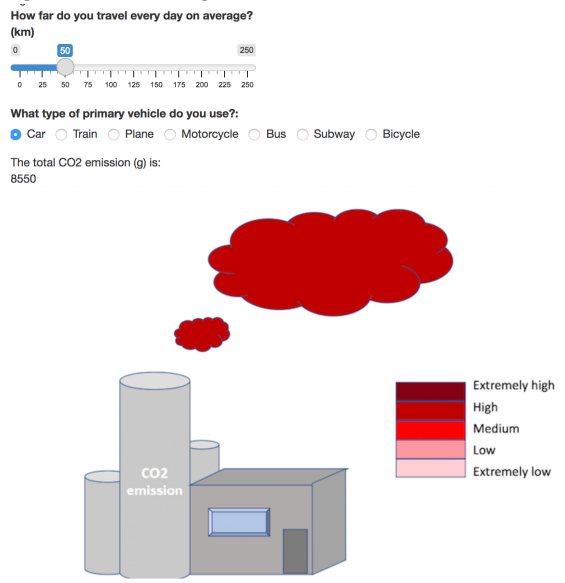

Figure 3.1

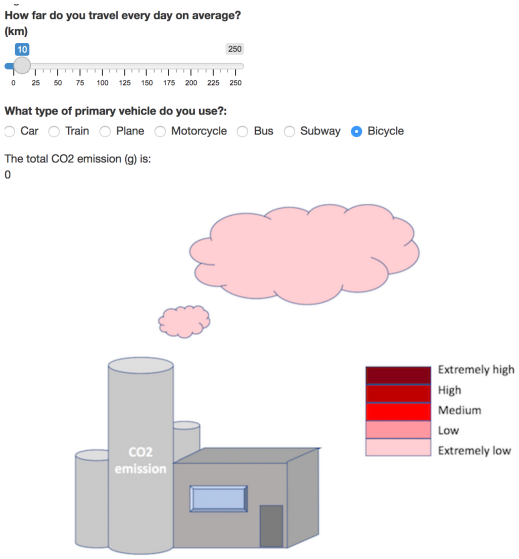

Figure 3.2

From the example visualizations, in Figure 3.1, if one person chooses to commute by car for 50km daily. By calculation, the interactive function in the shiny app in R, we can see the color is dark red, which stands for High level CO2 emissions. If one person commutes less than 10km with a bike in daily life on average. Then, in Figure 3.2 the CO2 emission level for him or her is Extremely Low level, which is in light red.

There are some limitations that it's not easy for people to determine how far they actually travel in their daily time, which will completely change the result of the calculation and the visualizations. Besides, in some situations, someone may commute by more than one means of transport, the survey in "What's your 'contribution'?" part is based on one primary vehicle, which will also lead to inaccuracy of the calculations and visualizations. Then, we display the *Impact of choosing alternative means of transport* visualization, in which users can compare all types of vehicles. In this visualization, we use different color hues to represent categorical attributes – types of primary vehicles. Based on the CO2 emissions per passenger per kilometer data, we can also find out the impact of choosing alternative means of transport. Also, you can compare all types of vehicles with the following graph. The different color hues to represent categorical attributes – types of primary vehicles. The slope of each line will be the amount of the CO2 emission per person per kilometer release with one type of vehicle. From the visualization, you can see the total CO2 emissions you release if you choose a different vehicle to daily commute 1 kilometer for 5 years. We can obviously see the difference among various types of vehicles along with the time. This can reflect the impacts on choosing alternative means of transport.

In "How Can You Help?", we aim to create visualizations that illustrate each type of vehicle's "selfishness" to the environment. In other words, we measure each vehicle's CO2 emission/km by one person and compare it with another type of vehicle to see the equivalent number of people it takes in using another vehicle to produce the same amount of CO2 output. The interactive activity can be used as follows: first, the viewers choose two types of transportations they want to compare. Next, viewers will see the corresponding

two vehicles presented side by side in a graph. According to the amount of CO2 emission of each chosen vehicle, we compare the difference in CO2 emission between vehicles and link the calculation of ratio in the server. After getting the CO2 emission ratio between the two vehicles, we present the finding by lining up **the approximate** number of people figures, standing in front of each vehicle to represent the equivalent level of CO2. Finally, we summarize the result in the sentence underneath the graph.

An example of this visualization would be, a person driving a regular 4 seats sedan that emits 200 g of CO2 after traveling 1km on one side. On the other side, we compare it with a bus traveling for 1km and each person contributes 20g of CO2 on average. Then, we would show 1 person traveling 1km by 4 seats sedan is equivalent to 10 people traveling 1km by bus.

The magnitude channel we chose to present the difference is by the number of people standing in front of the vehicle (2D area). The vehicle with fewer people standing in front is the vehicle that contributes more CO2 emission to our environment per person. Different from standard bar charts, this visualization not only clearly shows the difference in carbon emission, it also shows which means of transportation are considered more harmful to the environment. The colour choice of the people figure I chose was black and white standing right against each other. This particular colour choice is clear to see, easy for readers to count and some basic pop out effect that catches viewers' attention. On top of that, our goal for this activity is to condemn the "more selfish" means of transportations, viewers may feel emotionally driven to use the "less selfish" transportation that causes less damage to our environment after reading this article. One limitation to this visualization is that it constrains the viewers to only compare 2 vehicles, if they wish to compare another set of vehicles, they would have to manually change the choices.

The "Flatten the Curve" section consists of a short paragraph that restates our main point and the goal we hope people would strive for. It also includes several other key facts about vehicle use to further drive in our main point about choosing greener ways to travel. The CO2 emissions plot described in "Unsustainable CO2 emission" was revisited with the addition of data points that were calculated assuming more and more users adopt greener alternatives of travel. The main goal is to highlight how user action can potentially "flatten the curve" of CO2 emissions to more acceptable levels in the future and help save our world!

Reflection

Our team has met once or twice every week through Zoom to make a plan and timeline of the project and update each other on the work made. For the majority of the meetings, we also noted meeting minutes. During our initial meetings before the mock up, we used the whiteboard feature of Zoom to draw our ideas together and brainstorm with visuals. Each member was responsible for one section of the design. After finding datasets and exploring them, we finalized how much of our ideas can be used in the project. For example, we initially wanted to allow the viewer to see the CO2 emissions produced from the production of different vehicles alongside with the emissions from using them. However, due to very limited data options, we could not add this to our product. Moreover, we tried to use different programs to have more flexibility in terms of each member's strength. For example, we first thought about using ggplot and R to produce the static plots and Python and Jupyter Lab for the interactive part of the product. However, this separation of platforms would cause lag in collaborative work and confusion, so we decided to create a Github project using R Markdown and Shiny App for interactive visualizations. We had some challenges using Github and Shiny as most of us were new to both programs. However, members were always very responsive in the groupchat and helping each other when we had any problems. To give an example, we had difficulty creating pictures for some plots and icons such as in tree and car comparison in section 1 and icons in section 4. Other group members suggested websites and PowerPoint to find stock images and icons to avoid credit and drawing issues. After entering the finals period, we set small deadlines to keep ourselves on track.

Some limitations of our product are from the focus in daily travel. Even though we included the option of air travel, we did not give much importance for longer distance travel. For example, a progress that can be made is adding a section for longer distance travel with asking the user about their travel frequency and average distance they travel in these trips. Because one person might primarily use a bike as the mode of commute but also travel far distances by plane every month for their work, which would also be important to consider. Besides, in some situations, someone may commute by more than one means of transport, the survey in "What's your 'contribution'?" part is based on one primary vehicle, which will also lead to

inaccuracy of the calculations and visualizations. Furthermore, our flatten the curve part might need updating in the near future due to the changing world because of the pandemic. Even though we are slowly going back to "normal" life thanks to vaccination progress, many people might continue to work from home and many sectors are switching to the digital sooner than expected, which would reduce overall commuting and therefore CO2 emissions. This might affect our predictions of CO2 change for the next 10 years.

In the "How Can You Help?" section, we also faced some challenges when implementing the comparisons between vehicles. Firstly, the technology constraints of ShinyApp. In the design phase of this assignment, we were hoping the program would draw the creative graphic for us. However, shinyApp does not have features that draw creative graphics. In order to generate the comparison plots we had in mind, we had to manually draw all the comparison graphics in powerpoint slides which took longer time than expected. Furthermore, due to the manual drawing constraint, we had to cut down the number of vehicle options we let the viewers to choose from. At the end, we limit the options to 5 vehicles which still require 15 manual graphics. 10 (5 choose 2 =) from the different combinations of vehicle choices and 5 additional graphics that compare each vehicle type to itself.

One final challenge we faced was the accessibility of data and technology. For instance, car production data, that was freely available, did not include all countries and years. As a result, some functionality we planned for "Unsustainable CO2 Emissions" such as filtering the data by country and allowing the user to adjust the time period, were not included with the product. Further, the web deployment is slow and limited due to the shinyapps.io paywall.

Team Assessment:

As a team, The (Green)Power Rangers boasts a 100% participation rate in all team meetings and deliverables. The team also studied several new R libraries rapidly for use with the product.

Andrew

Andrew created the github repository as well as a short video tutorial on how to integrate version control with RStudio. Andrew was in charge of "Unsustainable CO2 Emissions" and "Flatten The Curve!" sections of the product. He also ensured that the final product was organized neatly and helped group members with debugging their R code.

Elif:

Elif suggested the idea of a "behaviour quiz" to show users how their routines affect climate change. She found reliable data sources and designed the Climate Change & CO2 101 section of the product with interactive pie charts. Moreover, Elif was responsible for recording meeting minutes to save the updates and discussions through the design process.

Ruei-Hung (Ray):

Ray constructed the backend server and the user interface for the "How Can You Help?" section using shinyApp library in R to deploy the interactive activities. Furthermore, Ray was responsible for collecting and cleaning the vehicle production data and the CO2 emission data collected from "Our World in Data". Throughout the project, Ray also facilitated the group meetings remotely through Zoom to ensure the workflow of the project is on schedule and follow the guidance of the project provided by the course instructor.

Zhenyu:

Zhenyu constructed the visualizations for various levels of the survey outputs. He raised the idea of interactive visualization for the "What's your 'contribution'?" section of this project. Zhenyu also contributed to the mock design for this project. He learned and adopted shiny app functions to implement the interactive graphics. Through the interactive graphs, he was able to analyze the visualization and plotted the impact of choosing alternative means of transportation in our final product.