Carbon Emission for Airplane

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ABSTRACT

With the increased usage of flights after the end of the COVID-19 pandemic, carbon dioxide emissions have been growing within the aviation industry. Our visualization tool targets users with some environmental awareness that may or may not be traveling out of Boston. The tool encourages users to select flights that have the lowest carbon emissions and to explore why some flights may have greater carbon emissions than others to expand their understanding of the industry. Therefore, through this tool, we want to motivate individuals to take greater control of their carbon footprint and make more environmentally-conscious choices.

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1 INTRODUCTION

Our visualization tool aims to promote greater environmental awareness by tackling the carbon emissions made in the air travel industry. With the industry accounting for over 2% of global energy-related carbon dioxide emissions, the aviation industry has been deemed to be ”not on track” to reaching net zero emissions by 2050 by the International Energy Agency [4]. However, environmental awareness has been gaining traction in many different communities, ranging from students at a Slovakian university [8] to Chinese tourists [6], potentially due to the rise of social media sites and the greater spread of information. We anticipate individuals with a growing interest in their own carbon footprint taking interest in our visualization tool.

The purpose of this tool is to assist users in choosing the most environmentally-friendly flight for their travels from Boston or New York City and to allow users to explore how and why different flights have different carbon emissions. Regarding the first purpose, we hope that users will reduce their own carbon footprint by selecting the flight with the lowest carbon emissions. By displaying the information and encouraging the user to be more aware of their choices, we wish for the user to leave our visualization with a plane ticket out of Boston and a greater drive for taking environmental issues into their own hands. As for the second purpose, even if our user has no intention to travel, we want individuals to explore the data we have and understand how the aviation industry has such high carbon emissions. The user should leave the visualization with newfound knowledge of the aviation industry and how they can possibly change their habits in the future regarding travel.

2 RELATED WORK

Finke et al. [5] proposed using the ”Lowest Impact of Deviation” principle to reduce CO2 emissions in air traffic management. The principle ensures that the aircraft consuming less fuel during an avoidance maneuver takes evasive action. Simulations show that this approach can reduce additional fuel burn due to de-conflicting by 10 percent. Implementing this principle is easy and inexpensive as existing Air Traffic Management (ATM) technology is compatible with it.

Although the focus of prior work is different, their visualization also simulates the routes of the flights using dots and lines, with dots representing the origin and destination, and lines representing the routes. We would like to use a similar visualization technique as shown in the paper for our use case. We planned to use a similar approach to visualize our own data, in which we would also incorporate a drop-down menu with different origin options. This would allow users to select their departure airport and apply filters to generate different visualizations. Also, with dot marks for origins and destinations and line width and positions of airports as channels, we would extend the visualization to fit our use case.

Liu et al. [7] assessed the contribution of international student mobility to aviation emissions. When it comes to percentage data, people visualize it with pie charts because of the nature of circles: the central angles allow for ease of access when plotting percentages. In particular, Liu et al. [7] developed a methodology for displaying the percentage of carbon emissions reduction by country through pie charts.

Although the focus of the research is different from ours, they visualized the emission reduction percentage compared with pre-COVID with pie charts by countries. By computing the percentage of emission reduction by country, they were able to visualize the derived data through a pie chart, which directly shows that China in first with 35.8% of the reduction, and India in second place with 18.5% of emission reduction. It inspires us to compute percentage data of carbon emissions per person per flight of total annual average carbon footage per person, and extend their methodology to visualize the derived data via pie chart with area mark, tilt channel, and provide environmental science information on the side. In that case, our visualization techniques would build upon previous research and offer a more interactive and aesthetically pleasing approach to presenting air travel data.

3 USE CASE

To assist users in determining the most environmentally-friendly way of traveling, we present our visualization tool, which aims to display two key points regarding air travel:

1. The flights an individual can take from Boston’s Logan International Airport or John F. Kennedy International Airport to another location of interest.

2. The carbon emission of that particular flight.

Suppose a traveler wishes to fly from Boston to New York City. This traveler has prior knowledge on global warming and how carbon dioxide contributes to that, but does not have extensive knowledge on environmental science. In particular, they have a growing interest in learning more about their carbon footprint and have started looking more into resources that advise them on where their personal emission can be reduced; however, emissions for flight data are incredibly scattered and always generalized to how the airline industry emits a high amount of carbon dioxide annually. Ultimately,

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the traveler is seeking a tool that allows them to compile data about all possible flight routes from Boston and to understand the carbon emission of their choice to make better, environmentally-friendly decisions for their travel.

With our visualization tool, the traveler can first select the flight and the location they would like to go from a map of all possible routes from Boston. Once they have selected their desired airport, John F. Kennedy International Airport, then the second paired visualization will update to reflect how much carbon that particular flight produces. The paired visualization will also compare the flight's carbon emission to other flights and other metrics the traveler may be curious about, allowing for further exploration and gaining of knowledge regarding their carbon footprint.

We hope that through the exploratory aspect of our visualization tool, users will be more cautious of their own footprint and make more environmentally-conscious choices when it comes to their purchases.

4 DATA

We retrieved and analyzed flight information by REST APIs through a comprehensive website [3] that offers many Application Programming Interfaces (APIs). Specifically, we extracted relevant attributes such as International Civil Aviation Organization (ICAO) codes, International Air Transport Association (IATA) codes, country names, and their corresponding latitude and longitude data from the Airport API. We limited our data extraction to flights departing from Boston Logan Airport and John F. Kennedy International Airport in New York City. To facilitate our investigation into carbon emissions, we further extracted distance information from Geopy library in Python, and obtained carbon emissions data from Aviation Emissions [2]. We then merged it with the attributes mentioned before to create a new CSV file.

After retrieving the raw data, the resulting dataset was found to be robust and reliable, with the exception of the "shortName" column which contained several missing values. However, after inspection, it was determined that the "shortName" column duplicated information present in the "name" column, and was therefore excluded from the dataset. The "icao" column was also excluded since it describes the same information as the "iata" column, and 'iata' is the more commonly used airport code format for most people.

Moreover, the dataset still lacks two crucial derived variables which are carbon emission per person per flight and the percentage of it to the average annual carbon footprint. The carbon emission per person column is computed based on the distance of the flight route. To accurately calculate carbon emissions, we applied a carbon emission formula [2] that is widely used in the aviation industry. This allowed us to derive the corresponding carbon emissions for the flights. Subsequently, we calculated the carbon emission per person to enable us to assess the carbon footprint on an individual basis. To contextualize this information, we referenced an article [1] discussing the average global carbon footprint and calculated the percentage of each flight's carbon emissions compared to this standard. The addition of these two derived variables makes our dataset more comprehensive and provides a clearer understanding of the environmental impact of the flights under consideration. We end up with a dataset with 368 rows and 11 columns.

Since we only looked at flight routes of two airports (BOS and JFK) and the API calls only offer flight routes data for the current year (2023), our data is not comprehensive enough to analyze all operating flight routes in the world, or even just in the United States. However, it does provide insight for people to choose the most environmentally-friendly flight from Boston or New York City.

Given that our data is extracted from APIs, it is essential that we handle the data with care and take measures to ensure that we do not violate privacy and safety regulations. Regarding our calculation of the derived attribute for carbon emissions, we assumed all flights were operated by a Boeing 737-400. This may result in some bias in our dataset concerning carbon emissions.

5 DESIGN PROCESS

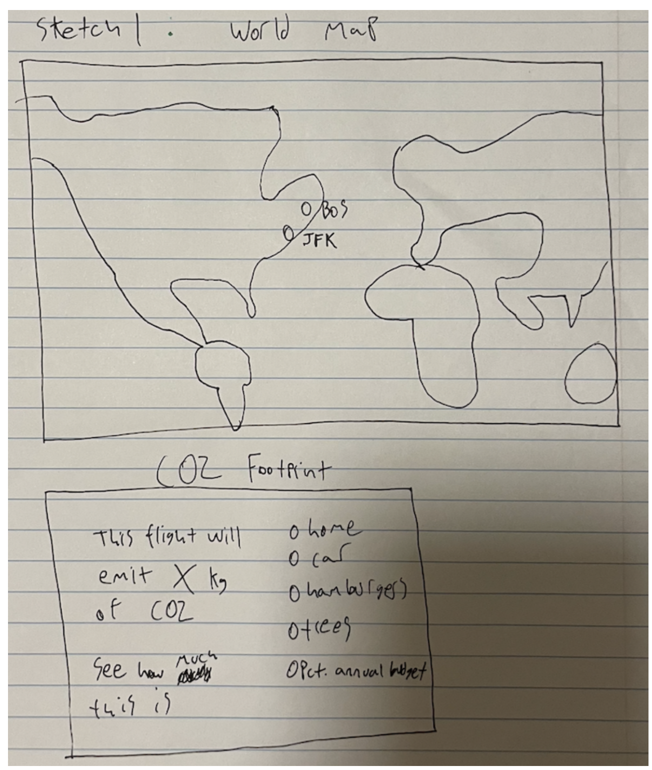

Figure 1: First sketch of our visualization based on our data

This initial sketch establishes the layout for our visualization: the combination of a world map showing flight routes and a linked view showing the carbon footprint of the selected flight.

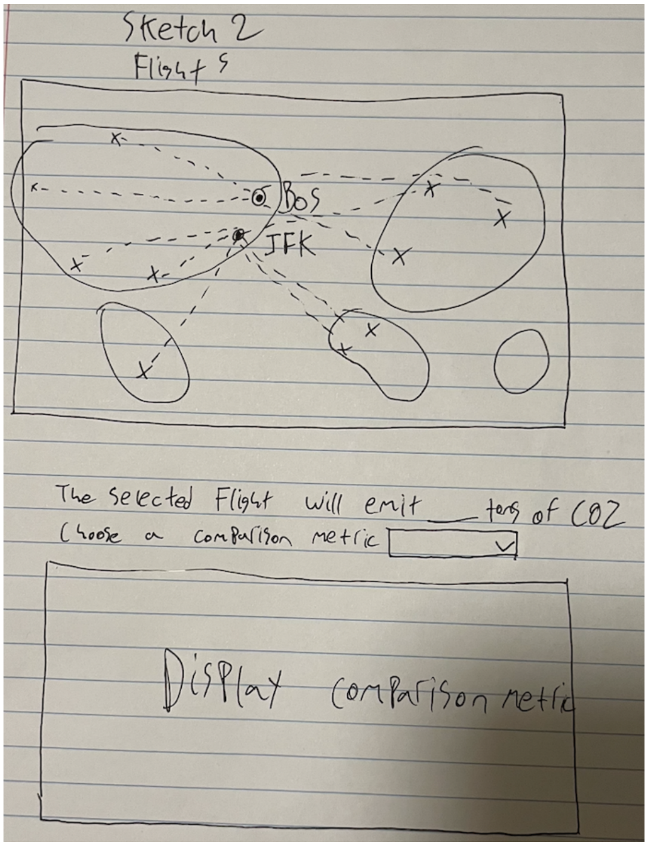

Figure 2: Second sketch of our visualization based on our data

This sketch expands on the first sketch by adding a drop-down menu that allows the user to select a metric to visualize the carbon footprint of the flight they selected.

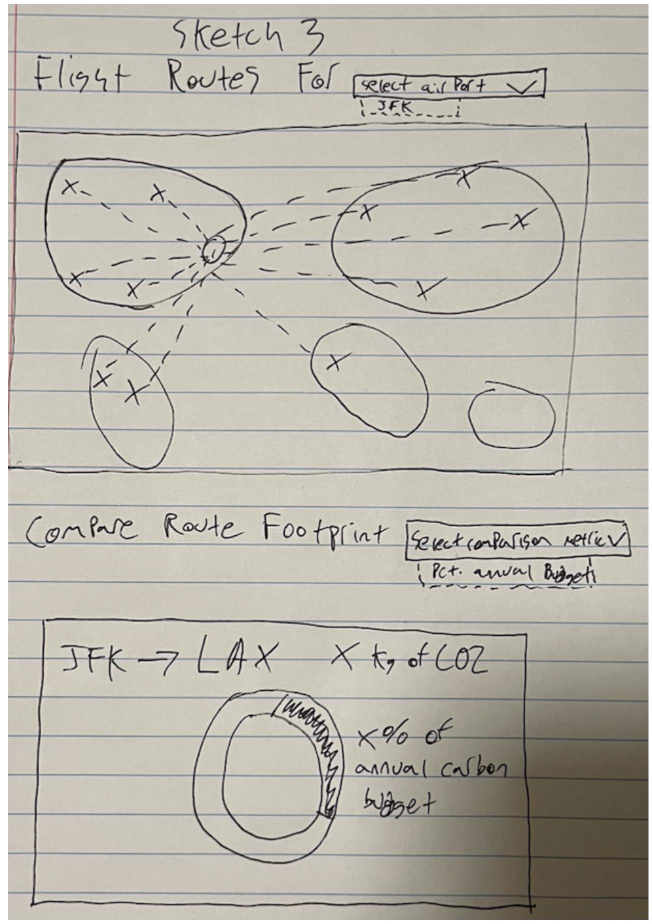

Figure 3: Third sketch of our visualization based on our data

This sketch gains further refinement towards the final product as it adds another drop-down to the first view. The new drop-down shows all the routes for just the selected airport on the map and allows the user to select the destination and receive emissions information on the route in the view below.

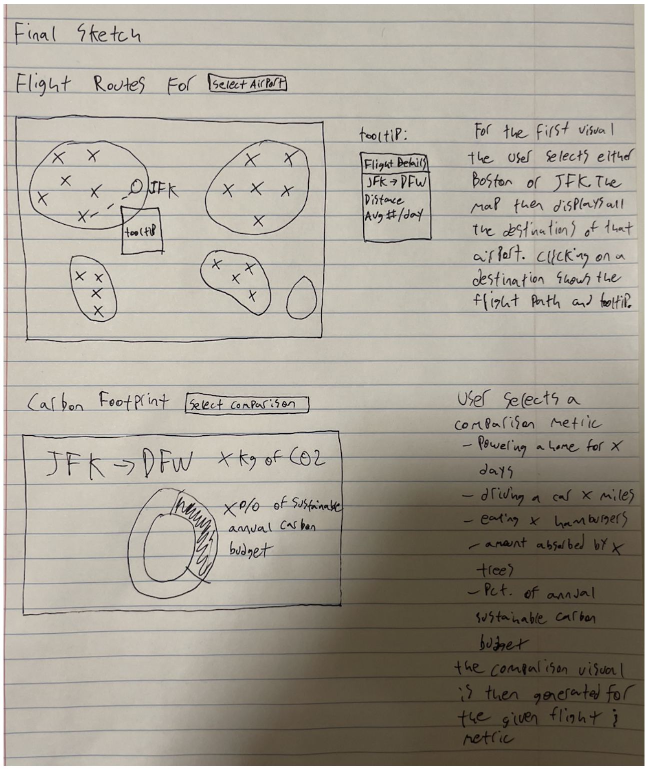

Figure 4: Final sketch of our visualization based on our data

The final sketch brings together all of the improvements of the previous drafts. It allows the user to select a departure airport, then displays all the destinations from that airport. The user can then select the destination and the flight route will display which, when hovered over, will display the tooltip showing route info. The selected route is then brought up in the second view and the user can select a metric to compare the CO2 emissions. The visualization uses a combination of area, points, and lines as marks to represent the countries, airports, and routes. The channels are position, shape, area, and size. These help represent location, type of airport (destination vs departure), and flight length.

The final visualization design was not changed extensively during the implementation process. However, it did undergo a number of evolutionary tweaks to optimize its performance. This came as a result of usability testing and analysis of how well the design was supporting its intended tasks. In the final sketch we had originally planned to make the second view contain a dropdown menu to display different comparison metrics but as our usability testers noted, this made analyzing their impact more difficult. This approach required them to switch between views instead of being able to digest the metrics all at once and compare them to each other. However, the remainder of the design remained the same as the sketch as our usability testers noted the map allowed for the quickest means of exploring different routes.

6 Final Design

Our final design incorporates channels and marks to facilitate communication between the different graphs in our interactive visualization. Our objective is to allow users to select points on the map, which will trigger the donut chart to display the corresponding percentage of average annual carbon footprint per person.

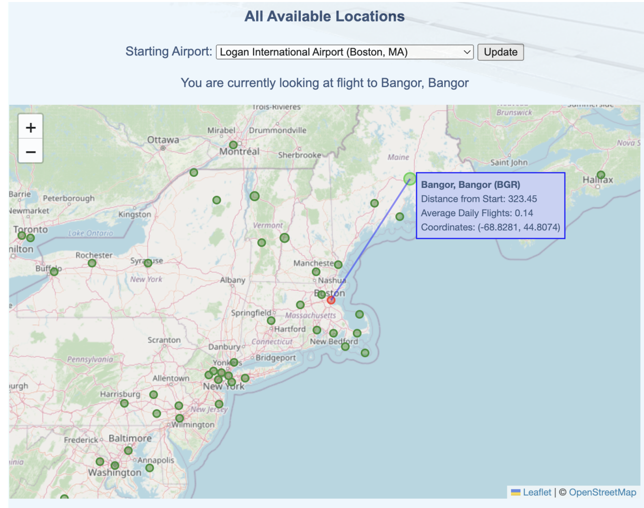

Figure 5: Final design of selecting flight routes

To begin, users can select either Boston Logan International Airport or John F. Kennedy International Airport from a dropdown menu. After selecting a departure airport, the map will automatically display the available arrival airport options. Users can then click on the green dot on the map to see the estimated carbon emissions for the chosen flight route. The thickness of the line is based on the average number of flights. The accompanying text will update to provide relevant information about the selected airport and city as users make selections and explore different flight routes.

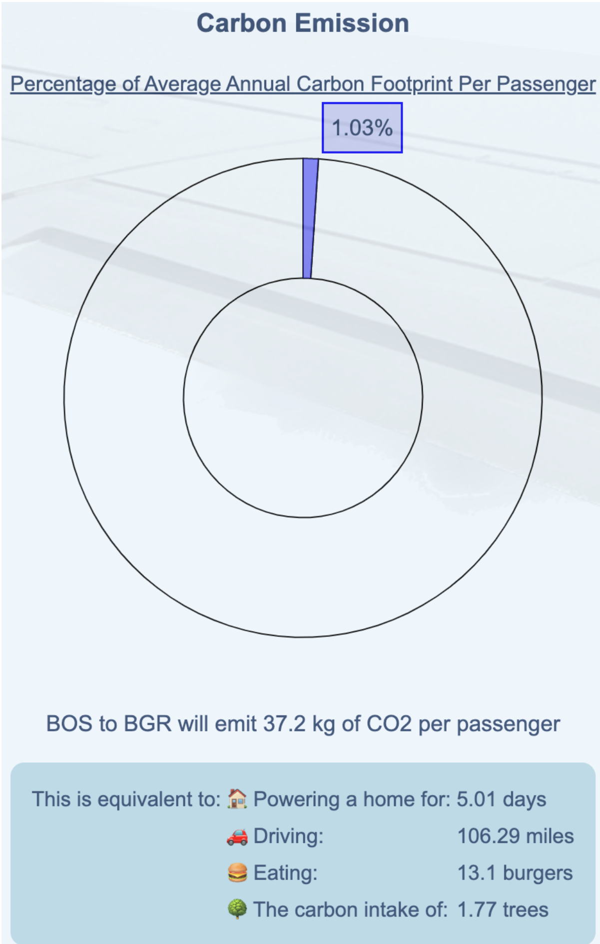

Figure 6: Final design of displaying carbon footage

In the donut chart visualization, we display the percentage of average annual carbon footprint per person taken for the chosen flight route. Every time a user selects a new flight route, the donut chart will update its corresponding percentage with a subtle animation. Users can see it when they hover the mouse over it. In addition, we provide information on the amount of carbon dioxide produced by the flight in kilograms at the bottom of the visualization. To help users better understand the scale of carbon dioxide emissions, we use relatable comparisons. Specifically, we provide information on how many driven miles it would take to produce the same amount of carbon dioxide, how many burgers one would need to eat to produce this much carbon dioxide, how long we can power a home, and how long it takes for trees to absorb the equivalent amount of carbon dioxide. This approach embodies the concept of carbon dioxide, allowing people to better comprehend the impact of their actions on the environment in their everyday lives. Overall, our design aims to provide an engaging and informative experience for users to learn more about the carbon footprint of air travel.

7 Discussion

Our objective is to encourage users to consider the environmental impact before taking a flight. To facilitate this, we have developed a tool that expands their understanding of environmental issues and provides greater control over their carbon footprint. During our research, we identified that the distance of the flight is the most significant factor influencing carbon emissions. As the distance increases, so does the amount of carbon dioxide produced. With the improvement in technology, some airplanes may already start to use more energy-efficient and environmentally friendly engines. If we can also take this into our consideration, the impacted factor of carbon emission can also be different engine types.

Furthermore, we recognize that our tool's departure airport options are limited to only two choices. This may restrict users who wish to evaluate their carbon emissions based on their country of origin. We understand the importance of providing a wider range of options to meet the needs of our users. So, we will work on this by adding more original locations to look at for users in the future.

8 Conclusion

In conclusion, our tool is intended to raise environmental awareness while also allowing users to make informed decisions about their carbon footprint. According to our findings, the most significant factor influencing carbon emissions is flight distance. Therefore, to contribute towards a more eco-friendly society, users of our tool are encouraged to limit long-distance flights as much as possible.

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Table 1: Carbon Emission related to Flight

iata	name	municipalityName	countryCode	lat	lon	from	averageDailyFlights	dist	co2KGPerPerson	percentageco2
DCA	...	District of Columbia	US	38.8521	-77.0377	BOS	27.81	641.97	73.83	2.03
JFK	...	New York	US	40.6398	-73.7789	BOS	21.14	300.3	34.53	0.95
MCO	...	Orlando	US	28.4294	-81.309	BOS	17.29	1804.03	207.46	5.72
LGA	...	New York	US	40.7772	-73.8726	BOS	15.88	296.86	34.14	0.94
ORD	...	Chicago	US	41.9786	-87.9048	BOS	14.53	1394.37	160.35	4.42
EWR	...	Newark	US	40.6925	-74.1687	BOS	13.68	322.52	37.09	1.02
ATL	...	Atlanta	US	33.6367	-84.4281	BOS	13.29	1522.4	175.08	4.82
PHL	...	Philadelphia	US	39.8719	-75.2411	BOS	11.43	450.44	51.8	1.43
CLT	...	Charlotte	US	35.214	-80.9431	BOS	11.01	1171.14	134.68	3.71
FLL	...	Fort Lauderdale	US	26.0726	-80.1527	BOS	10.94	1991.09	228.98	6.31
TPA	...	Tampa	US	27.9755	-82.5332	BOS	10.29	1906.62	219.26	6.04
...	...	...	...	...	...	...	...	...	...	...

A Data Abstractions

Our dataset is presented in a **table** as in Table 1: Carbon Emission related to Flight. The data type of rows is **items**. Each item represents a flight route, with origin airport code indicated in ”from” attribute (BOS or JFK), and destination airport code indicated in ”iata” attribute.

There are 11 columns in the dataset. ”iata”, ”name”, ”municipalityName” **attributes** are all representing the name of the airports, and they are categorical data. ”countryCode” and ”from” attributes are also categorical. ”lat” and ”lon” are latitude and longitude of the destination airports, which are both **position**. ”averageDailyFlights” **attribute** represents the number of average flights on the route everyday, and they are ordered, quantitative, and sequential. Similar to the **attribute** types of ”averageDailyFlights”, ”dist”, ”co2KGPerPerson”, and ”percentageco2” are all ordered, quantitative, and sequential. ”dist” attribute represents the distance between the origin and destination, ”co2KGPerPerson” represents the carbon emission per person per flight (in KG), and ”percentageco2” represents the percentage of the ”co2KGPerPerson” taking in 4 tons [1] of average annual carbon footage per person.

B Task Abstractions

Using Munzner’s visualization task taxonomy, we have translated our domain tasks into tasks that our visualization should support.

Our first domain task is to see which flights have the lowest carbon emission.

- The high-level task is then to **discover** the data, as the user is given all of the data and can look through all of it to arrive at their own conclusions.
- The mid-level task is to **locate** the data. The user wants the flight with the lowest carbon emission, so the target is known, but the location is to be discovered.
- The low-level task is to **identify**. The goal of this user is to look for one specific flight, so this would be an identifying task.
- The target is **attributes/one/extremes**. As we’re looking for the minimum value for carbon emissions, given a dataset of specific flights and their carbon emissions, we are only focusing on the extremes of one attribute.

Our second domain task is to explore the dataset and to better understand why some flights may have greater or lower carbon emissions.

- The high-level task is, similarly to above, to **discover** the data. The user is provided all of the data and is being asked to search through it for their answers.
- The mid-level task is to **explore** the data. Unlike above, there is nothing specific that the user is looking for; they are viewing the data at a whole to arrive at their own conclusions.
- The low-level task is to **compare** the data. There are multiple targets that the user is looking for, and they want to identify the differences between their carbon emissions and some other attributes (i.e. distance of flights, size of plane, etc).
- The target is **attributes/many/similarity**. The user would be looking for which flights are similar in their emissions and why that is, as well as why flights have such different carbon emissions. We would need to look at many different attributes and see similarities/differences to answer this question.