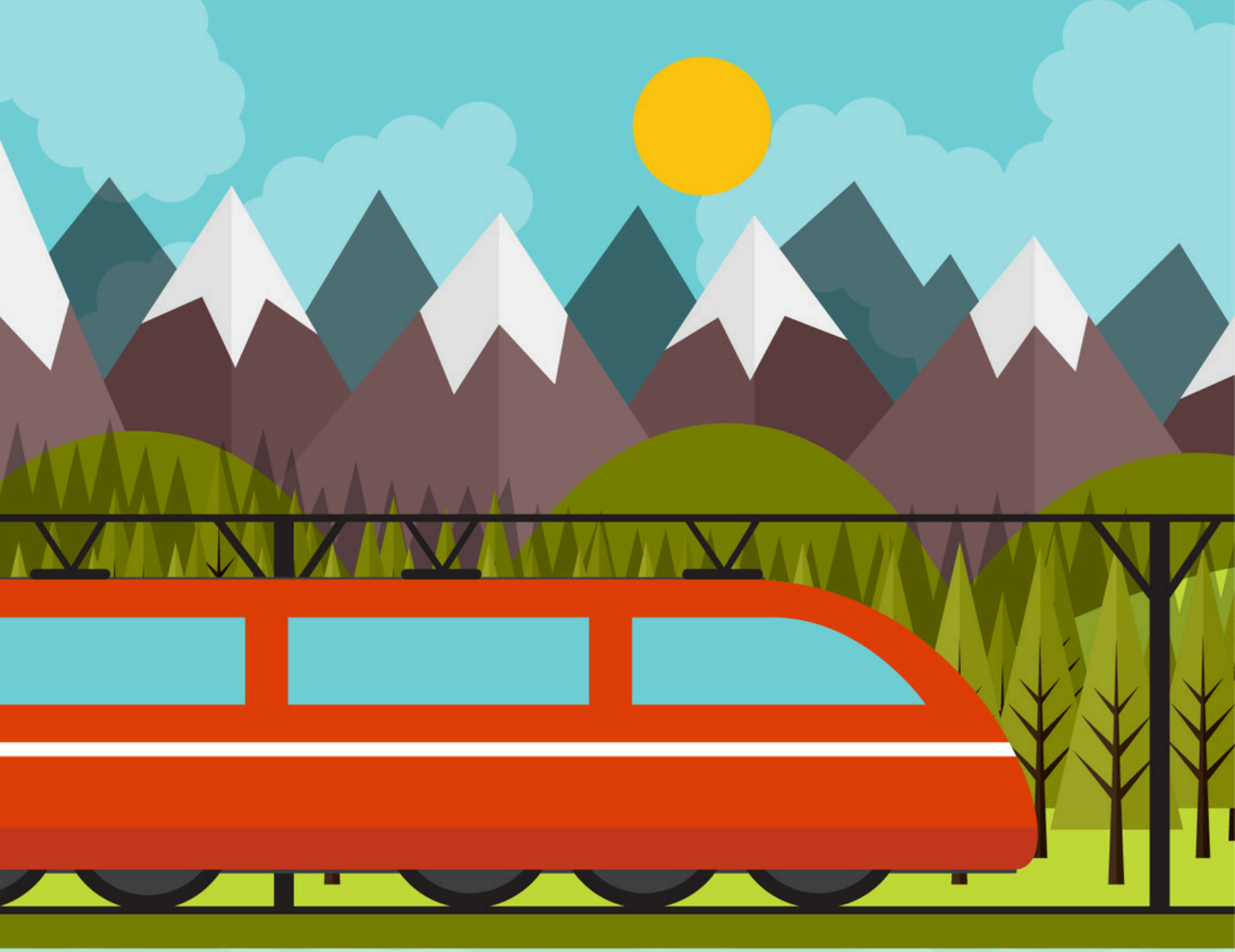

EcoRoutes:
The carbon cost of transportation

Process book

Stefan Krsteski
Andrea La Grotteria
Matea Tashkovska

COM-480: Data Visualization
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Motivation

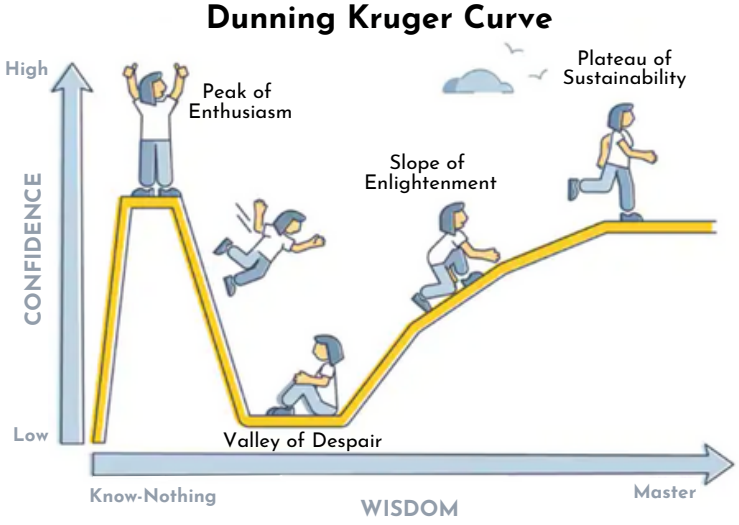
The beginning of this journey was marked when the team met. We discovered that we share two important things in common: **love for travel** and **commitment to the environment**. During our initial discussions, we stumbled upon data from the EcoPassenger website, which calculates the environmental impacts of various transportation modes between two cities. Knowing that concern over CO2 emissions has grown over the past few decades, and travel is a major contributor to this issue, this presented a significant opportunity for us to influence travel behaviors through data visualization. Motivated by these common interests, we decided to build **EcoRoutes** - a website designed to make passengers aware of the environmental impact of their transportation choices.

Dataset

As three motivated companions, we took on the first challenge - the dataset. We turned to the EcoPassenger website, which provides detailed information on CO2 emissions, energy consumption, and other environmental impacts for various modes of transport. After further research we discovered EcoPassenger was developed by the International Railways Union which use well-verified and documented methods for calculating the environmental factors, proving the reliability of the data.

However, we identified a key issue with the website - it lacked visual appeal. The data was accessible only through text-based outputs via two search bars, making it difficult for users to engage with and interpret the information. This limitation sparked our idea: why not retrieve the data and display it in a visually appealing manner?

We soon discovered that we were standing at the top of the Dunning-Kruger effect curve - the Peak of Enthusiasm; as we came face to face with the task of manually scraping the dataset. Eventually, we moved past the Valley of Despair and reached a Plateau of Sustainability, where we managed to successfully extract a comprehensive dataset.



More specifically, the dataset includes travel times and environmental impacts (carbon dioxide emissions and energy consumption) for various modes of transportation (cars, trains, planes) between cities. We carefully chose 90 cities across Europe based on their size and popularity. After conducting exploratory data analysis, we decided not to pursue the car as a mode of transportation for further exploration, since there was a perfect linear correlation between CO2 emissions and distance, which wouldn't provide any additional insights; users could simply calculate emissions based on distance alone. To enhance the story, we further expanded our data by including geographical information such as departure and arrival countries and regions. This way, we have collected a rich dataset that allowed us to conduct a more detailed analysis of country-level and regional travel patterns and highlight areas where transportation policies can be improved to support greener travel options.

Goals

Our primary goal is to encourage more sustainable travel practices by making it easier for users to understand the environmental impact of their travel choices. We aim to achieve this through interactive visualizations that compare CO2 emissions across different transportation methods (trains and flights) and highlight the most eco-friendly routes, both locally and globally. By presenting data in a visually engaging manner, we hope to inspire changes in travel behavior and transportation policies that favor sustainability. We believe our story will promote a **shift towards a greener future.**

Implementation

After we set our goals straight, another key component followed - brainstorming ways to visualize and communicate this data, aiming to guide users toward making choices that are as good for them as they are for the environment.

During our brainstorming sessions, we focused on the story we wanted to tell and the most effective ways to achieve our goals. After extensive creative thinking, exploration, and sketching, we decided on four distinct visualizations. The journey begins with a broad visualization offering users maximum flexibility to explore diverse travel options - from lengthy journeys to different modes of transportation. This gradually transitions to broader visualizations: the second visualization focuses on local travel and subtly promotes its environmental benefits, the third expands the scope to illustrate how different countries manage their carbon emissions, and the final one offers a comprehensive regional analysis that provides valuable insights for policymakers and researchers. This way, with each stage we are deepening the level of understanding for the user.

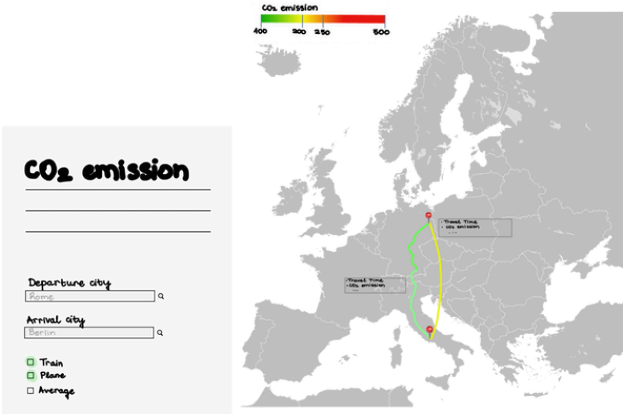
Additionally, we discussed and paid careful attention to our color choices. For the entire website, we aimed for a minimalistic and intuitive design, with the main colorful elements being the color gradients from the visualizations. This way we wanted to achieve a clean aesthetic, and also ensure that the visualizations stand out and really catch the user's eye.

Now let's explore the *journey*
of creating each visualization!

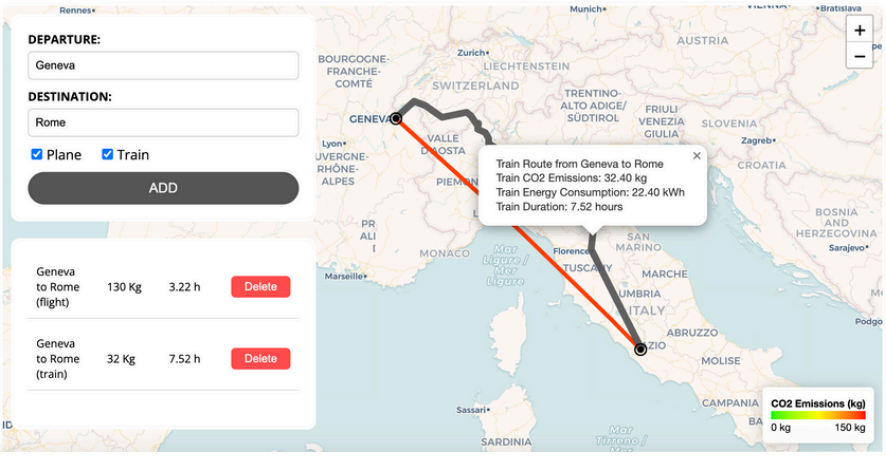
Eco Explorer

Functionality and Purpose

To present the geospatial aspects of our data, we decided our welcoming visualization to be a full-screen map of Europe with interactive components, allowing users to select their route and compare means of travel based on travel time, CO2 footprint and energy consumption. The purpose of this visualization is to enable users to explore desired destinations and compare eco-friendly travel options.



The main feature of our interactive map is the search, which allows users to select both departure and arrival cities, while also filtering by transport type. We added a hover effect over the routes displaying different variables, such as CO2 emission, duration and energy consumption. To enrich it visually, we color-coded the routes according to the amount of CO2 emissions, with the color legend shown in the bottom right corner. From the panel, users can dynamically add or remove routes as needed. We developed this map using Leaflet, which supported the display of the European map, incorporated D3.js to manage data interactions and used GeoJSON for drawing the lines. Our final product has met our initial idea in both functionality and design.



Challenges

A significant technical challenge was incorporating the kml files using the leaflet-omnivore module, which is not included for out of the box usage and required us to develop a custom TypeScript declaration file to bridge the JavaScript API. Additionally, achieving the overall look of the website and the precise positioning of the search functionality was challenging. This required some important design choices to ensure a seamless and user-friendly experience.

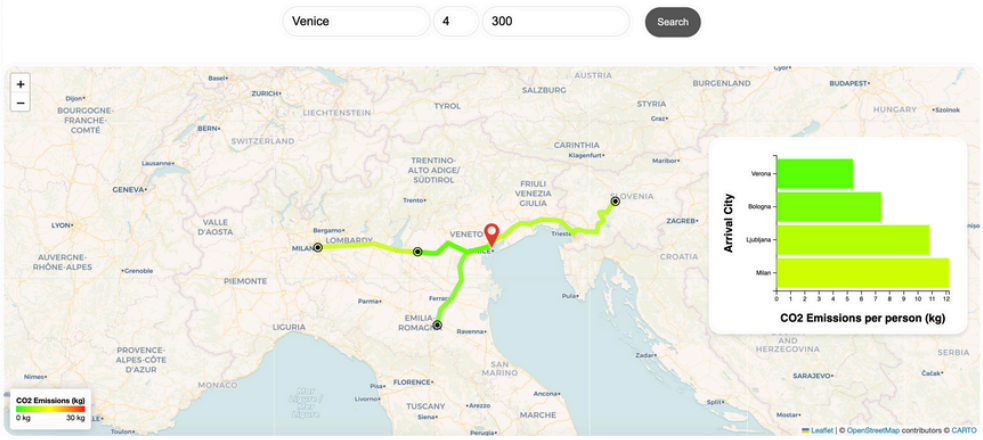
Drop A Pin

Functionality and Purpose

With our first visualization, we offered users complete freedom to explore various routes. In contrast, this visualization slightly constrains that freedom by offering pre-selected insights and routes, inspired by modern travel trends, where individuals typically visit a central location and explore its surrounding cities.

In this visualization we let the user select a starting city, number of destinations and maximum travel distance. The map then zooms in on the selected city and highlights the top-K routes to destinations with the lowest train CO2 emissions. Each route is interactive, providing detailed information upon hovering, similar to what we presented on the first visualization. The routes are color-coded according to their carbon footprint for clear visual differentiation.

This visualization was very similar to our initial sketch, however we went beyond our Milestone 2 proposal, and we enhanced the initial sketch with interactive bar plots. The bar plots allow the users to easily perceive differences of CO2 levels between destinations, as they are sorted from least to most producing CO2. For this visualization we used D3.js for both the dynamic mapping of routes and the creation of the interactive bar plots, in conjunction with Leaflet and GeoJSON for the geographic displays. Our purpose is to raise awareness of accessible, low-emission travel options and most importantly, encourage local travel.



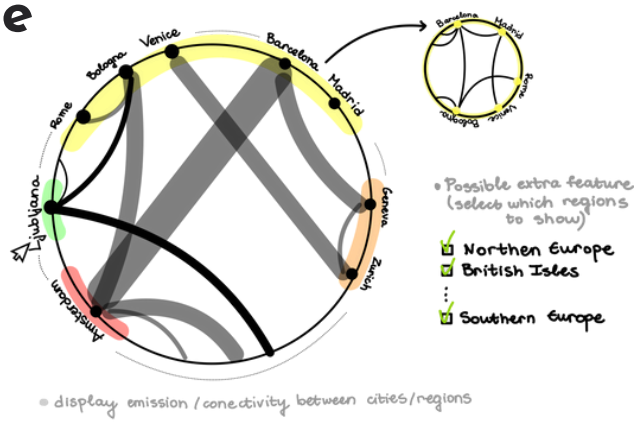
Challenges

Our main challenge in this visualization was efficiently orchestrating the data integration for both the map and bar plots. Balancing the complex requirements for each format required careful data management to ensure smooth performance on the website. Additionally, selecting an effective color scheme posed its own set of challenges. Initially, we considered using the route with the highest CO2 emissions as the benchmark for our color gradient. However, the maximum CO2 route in our data is the one between two cities which are really far apart and this approach did not effectively represent local variations in emissions. Instead, we decided to adjust the CO2 measurements to reflect local variations. This adjustment provided a more accurate visual representation of CO2 differences between local routes, better aligning with our story of promoting environmentally friendly local travel options.

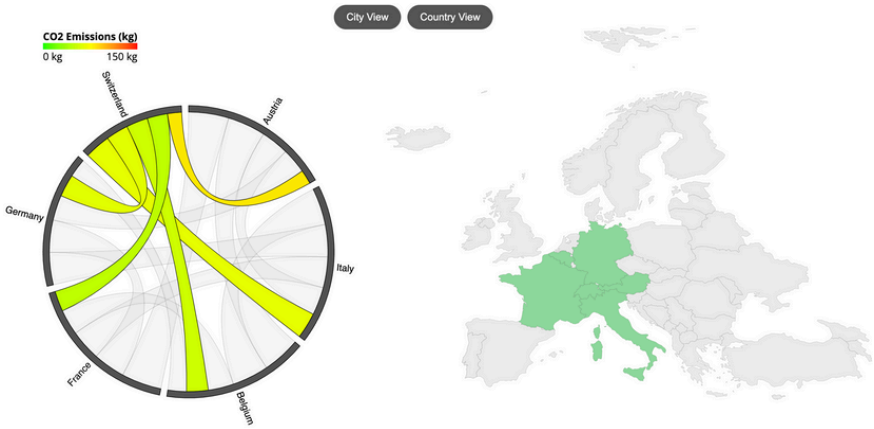
Eco-Network

Functionality and Purpose

In our third visualization, we present a circular layout graph with adjustable filtering options that allow users to scale the graph to different levels. Each edge in the graph represents a connection between nodes, where each node can represent a city or a country. The aim of this visualization is to expand the scope and highlight differences between national travel patterns, offering a coarser-grained view.



We decided to follow our initial sketch while incorporating minor improvements for enhanced functionality. Originally, we weighted the edges based on average CO2 emissions, but found out that some edges were barely visible due to their small size. To address this issue, we augmented our strategy to represent the average CO2 emissions through the color of the edges as well, ensuring that all connections are easily noticeable. Hovering over a node highlights all connecting edges, with colors indicating the carbon emissions of each route. To further enhance the user experience, we replaced our initial concept of selecting countries from a list with an interactive map of Europe on the side, allowing users to click on a country they wish to display on the graph. This gives the users flexibility to explore data dynamically and personalize their interaction based on their specific interests or travel plans. By selecting a country, the graph dynamically updates by adding or removing the corresponding nodes and reflect changes in both city and country views. For the Eco-Network we mainly used D3.js. This visualization serves as a smooth transition from focusing on individual cities to broader insights at the country level, impacting the travelers and also highlighting areas where transportation policies can be improved for greener travel.



Challenges

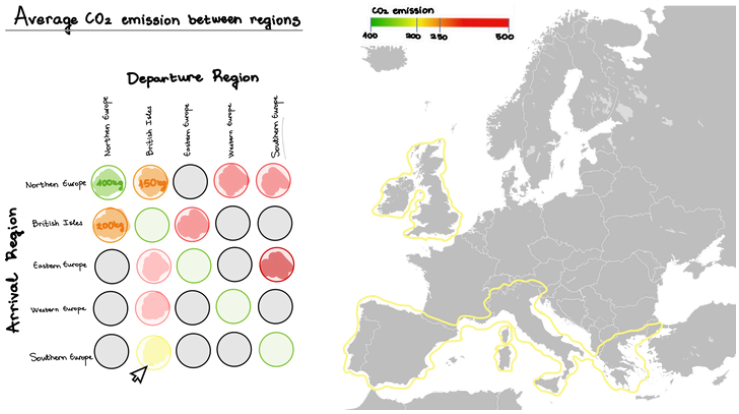
This visualization turned out to be the most challenging one to create. We faced two main difficulties: the data manipulation to switch views between city and country, and the necessity for complex modifications of the D3.js functions. Our graph is inspired by a chord diagram but significantly altered. Traditional chord diagrams use an asymmetrical matrix where each node displays varying outgoing edge weights. For our purposes, we altered this setup to maintain a symmetrical matrix, ensuring that the visualization accurately shows the bidirectional nature of travel between cities or countries. Another significant challenge was setting up the interactive svg map and its interaction with how the graph updates. This was challenging because we needed to dynamically change both the city and country views. Despite the challenges we made sure that this visualization allows users to easily and on demand explore the complex data and discover insights into national travel patterns.

Regional Emissions

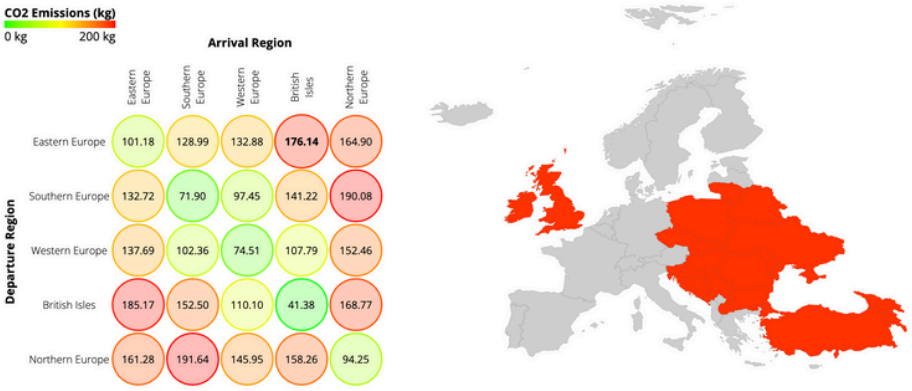
Functionality and Purpose

After going from full exploration to local travel and nearby cities, then expanding the scope to include countries, we now finally present the largest scope - regional level carbon emissions. The main feature of this visualization is the matrix, displaying the average CO2 emissions for all possible combinations of departure and arrival regions. By hovering over the elements of the matrix, the corresponding regions are colored on the map to show the average emission when traveling between those areas. This approach allows us to visualize the regions that are most sustainable, as well as those that are most in need of improvement.

Just by looking at a single row, we are able to extract a lot of information about the average emissions for trips originating from that region. This visualization builds on our previous ones and offers a broader perspective on travel emissions.



To create this visualization, we primarily used HTML/CSS tables to create the matrix and its interactive elements, as well as an svg map. The final product is exactly the same as our initial sketch. The overall goal of this visualization is to deliver valuable insights to the users about the regional relationships and deepen their understanding of the global environmental state.



Challenges

This visualization was the least challenging one to create since we reused some of the elements from the previous visualizations such as the svg map, the coloring scheme and some of the hover effects. The main challenge was creating the correlation matrix, as it required computations of the average CO2 emissions from the data to accurately represent it. Overall, by the time we began this visualization, we had become more proficient with the development frameworks, which facilitated our work.

Future Improvements

The best and easiest improvement can be done by including more cities. Ideally we would first expand to cover all cities of Europe and as an even more ambitious goal - expand to other continents. This can bring an even bigger improvement in itself, as intercontinental travel can be done with more transport types, and expanding to include cars and boats will further enrich the website. Furthermore, implementing real-time data updates could significantly enhance our visualizations. This feature would be particularly valuable at national and regional levels, allowing users to monitor the evolution through time and assess whether countries are effectively reducing their carbon emissions. This addition would make our platform even more relevant and informative for both frequent travelers and policymakers.

Ending Notes

As we approach our final destination, we hope you enjoyed the journey and exploration of the views along the way. We saw how this project evolved starting with the initial idea, voyaging through our thought-process and story. The story starts by giving you freedom, a way to explore, and as we go, we focus your attention on what matters by guiding you through our data. With this story we hope to promote our goal and inspire good travel choices. Now, it's your turn to explore the website and discover new ways to travel responsibly, one trip at a time.

Peer Assessment

Every team member contributed with equal effort and enthusiasm to this project, showcasing their unique skills. By complementing each other's strengths and collaborating seamlessly, together, we formed a great team!

Andrea 

Wrote the initial scraping, launched and orchestrated the website, its style and the overall flow. Responsible for the Eco Explorer and Regional Emission Visualizations. Helped for writing the text for the website.

Matea 

Helped with scraping, and exploratory data analysis, drew the initial sketches by hand, was responsible for the Drop A Pin visualization, designed the process book, and stylized parts of the website.

Stefan 

Helped with scraping, conducted exploratory data analysis, made the Eco-Network visualization, helped with the barplots for the Drop A Pin visualization, wrote the text for the website.

We hope you enjoy our website as much as we enjoyed making it!

Website Github