Visualizing Plastic Pollution

Ashraf Bade Elisabeth Leung Justin Woo Shivi Sood

ABSTRACT

Plastic pollution is a prevalent issue in today's world as it has detrimental effects on the environment and marine life. We propose a visualization that would allow one to see the consumption of plastic by each country and continent as a whole. This visualization tool would fill a gap between not visually seeing what areas in the world are the most responsible for plastic pollution. It would help the average person be more aware of their habits when it comes to the disposal of plastic waste. Policymakers would benefit from seeing what proportion of plastic waste is insufficiently disposed of and littered worldwide. They can put the necessary regulations and policies worldwide to combat this issue.

Link to Github Repository

1 INTRODUCTION

Plastic waste pollution has become a severe matter negatively affecting our environment. As plastic production continues to grow, the amount of plastic discarded into waterways and ultimately oceans increases. Plastic is used frequently in our everyday lives from bottled waters, straws, shopping bags, and many more. Plastic is also known for being a durable and inexpensive material that has led to many advancements within the technology, infrastructure, automotive industry, and medical industry. Although we could not imagine the world we live in today without plastic, the major issue with plastics is that they take many years to decompose, which has detrimental effects on the environment. As plastic bags are dumped into landfills and decompose, they emit dangerous greenhouse gasses. When plastic is not disposed of correctly, it can also lead to littering and blockages of stormwater drainage. Plastic also poses a significant threat to marine life as many animals get caught in the plastic or confuse it with food leading to choking or even death. Plastic pollution is primarily prevalent in developing countries with inadequate plastic waste management systems. However, this issue still plagues developed countries given the nature of plastic and its difficulty in being recycled. This issue requires everyone in the world to step up and do their part in being more aware of their actions and how it harms the environment. Therefore, a visualization that shows the amount of plastic each country produces and disposes inadequately or litter would benefit the country's citizens in understanding the severity of the issue.

2 RELATED WORK

1. G. F. Clark, J. Gacutan, R. Lawther, E. L. Johnston, H. Tait, T. Bednarz. A Visualization Tool for Citizen-Science Marine Debris Big Data. *Water International*, 46(2):211-223, Mar 2021

   Summary
   This peer-reviewed article is intended to describe the design and structure of a visualization tool designed to aid marine scientists in Australia to identify the distribution of marine debris. I think the tool being described in the article shares distinct characteristics with the project we are about to embark on. Therefore, the information within the article could inform us on how best to visualize the data, potential challenges with the visualization and how to technically structure our visualization tool for maximum effectiveness.

2. C. Veesommai and Y. Kiyoki. An analytical relationship retrieval scenario with temporal information data approaching to plastic waste-leaks into marine environments.*2019 International Electronics Symposium (IES)*, 2019, pp. 320-324. doi: 10.1109/ELECSYM.2019.8901571

   Summary
   This journal addresses the issues in the hazard and dramatic increase of plastic waste. Although the research conducted focused on plastic waste in only Thailand, its visualizations can be very useful and relatable for our group. One of the main things achieved by this source was to find correlations between various variables such as plastic production in-country, exported plastic production, imported plastic production, plastic production use, etc. to plastic waste. A heat map was created to visualize this and we believe that our group can incorporate a similar visualization. They also produced a model that gave insights on the correlation coefficients of each variable. Also, a model to predict the amount of plastic leaked into the environment, amount of plastic leaked into the ocean, and plastic debris was created and was accurately predicted and visualized with actual data. Relating this to our project, more data would likely need to be found in order to produce an accurate model, but it would be very interesting if we could do this as well. Overall, this resource provided information on how different variables relate to each other and how they affect overall plastic waste in the environment which is very similar to our goals for this project.

3. Z. S. Mazhandu and E. Muzenda. Global Plastic Waste Pollution Challenges and Management. *2019 7th International Renewable and Sustainable Energy Conference (IRSEC)*, 2019, pp. 1-8. doi: 10.1109/IRSEC48032.2019.9078268

   Summary
   This journal visualized the extent of the issue of plastic waste world-wide. It uses visualizations for various different purposes, with one being a line graph that visualizes trends of plastic waste over time, which is something our group can incorporate as well. Also they created several bar-graph visualizations to compare variables (countries) with how much plastic waste each produced. The dependent variables were slightly different for each, such as average plastic waste per person for each country, global share of plastic waste per country, amount of mismanaged waste per country, etc. We were planning on producing some visualization that compared countries and/or continents and this is definitely one visualization we can consider. Overall, this source provided great insights on how to compare variables on a visualization and also how to visualize trends.

4. J. Rojas. Plastic Waste is Exponentially Filling our Oceans, but where are the Robots? *2018 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*, 2018, pp. 1-6. doi:

10.1109/R10-HTC.2018.8629805

Summary

This journal addresses the lack of attention the world has on this issue with plastic waste and does a great job of using visualizations to exemplify the extent of the problem at hand. The visualization that was most memorable was the comparison of plastic waste produced and mishandled on a world map. Pie graphs were utilized on top of the graph for each country. This graph has many variables:country, coastal population, plastic produced vs. plastic mishandled, and the amount of plastic waste per day. Despite there being so many, the visualization was not chaotic due to the effective choices in channels, such as size, position, and color, all variables were able to be put onto one visualization. Overall, I think that this source produced a very creative way to incorporate many different comparisons regarding our topic and we hope to be able to recreate something like this.

5. E. Aretoulaki, S. Ponis, G. Plakas, K. Agalianos. systematic meta-review analysis of review papers in the marine plastic pollution literature. *Marine Pollution Bulletin*. Dec 2020; 161:111690. doi: 10.1016/j.marpolbul.2020.111690

Summary

This peer reviewed article takes a meta approach to the intersection between plastic pollution and data visualization. The article is a systematic analysis of other peer-reviewed articles and review studies that discuss marine plastic pollution. The writers process over 144 studies and analyze specific attributes such as research subjects, review types, geographical distribution of authors. All this data and more is later aggregated into descriptive statistics and visualizations. This unique approach could offer our group alternative perspectives on the well documented issue of marine plastic waste. In essence, it could be more fruitful to assess the context around the issue rather than the issue itself. The analysis and visualizations from that perspective would be more novel, potentially more insightful and impactful to our target audience

3 Use Case

Plastic pollution and single-use plastics have contributed significantly to today's environmental issues. Especially, given the fact that single-use plastics account for 40 percent of plastic produced every year and many of these single-use plastics persist in the environment for hundreds of years, highlights the gravity of this issue. Plastic waste is mainly known for its detrimental effects on wildlife, affecting nearly 700 species, including endangered species. To combat this issue, it's essential to understand which countries produce the most plastic waste, what proportion of that plastic waste is being mismanaged, and what proportion of the plastic waste is thrown into rivers daily by metric tonnes. Typically countries with a higher GDP tend to produce more plastic waste per person, but they all differ in the amount of mismanaged plastic. For instance, China and the United States are great producers of plastic; however, China has a significantly larger proportion of mismanaged plastic waste than the US.

Therefore, a visualization tool that shows plastic pollution across different countries, taking into account their economic status, would be beneficial for policymakers within the respective country to make decisions on reducing waste and promoting the reuse of single-use plastics. The end-user of this visualization could also be the average person as it would be beneficial for them to understand how bad the current situation of plastic pollution is within their country and have them reconsider their habits when it comes to recycling and littering plastics on both land and water.

4 Data

The data contains information about each country and their waste generation, plastic waste generation, inadequately managed plastic waste, and plastic waste littered in kilograms per day. The dataset includes the waste generation rate and the mismanaged plastic waste in kilograms per person per day. The dataset provides the mismanaged plastic waste in 2010 in tonnes and the projected mismanaged waste in 2025 in tonnes. It also provides variables such as economic status and the coastal population that could directly influence the generation of plastic waste and mismanaged plastic waste for a country. Biases in the dataset could exist from the fact that lower income countries typically have greater plastic waste pollution. Also, the coastal population being greater in a country could influence that dataset to be biased in showing higher plastic pollution for these regions.

https://www.science.org/doi/10.1126/science.1260352
Data in resources section as excel file

5 Task Analysis

Task ID#	Domain Task	Analyze Task (high-level)	Search Task (mid-level)	Analytic Task (low-level "query")
1	I want to be able to show my team the comparison between two specific different countries with their plastic waste metrics.	Consume → Present	Lookup	Compare
2	I want to identify how correlated economic status and coastal population per country are to waste generation in order to prioritize the team's efforts to reduce it.	Consume → Discover	Browse	Summarize
3	I want to show my team how each country mismanaged plastic waste projections for 2025 match their waste metrics from 2010 in order to determine strategies to minimize the reduce the predicted waste generation	Consume → Present	Browse	Identify

Final Review

The primary consumer of the visualization will be members of the Working Group III Mitigation of Climate Change. As plastic pollution is one of the biggest contributors to climate change, it would be very insightful for this organization to be provided with the visualizations of our project. Our visualizations will efficiently present the data set to allow the user to easily ingest the information and create value from it. The type of consumption that will be primarily developed for is present. This is because the user will be utilizing the insights in which the visuals already provide, but then interpret and connect it to climate change issues that the organization specializes in.

6 Implementation Plan

List of Visual Encodings:

1. Bar chart
2. Scatter-plot
3. Heat map
4. Spider web map

List of Interactive Components:

1. Selecting
2. Filtering
3. Zooming
4. Brushing and Linking
5. Change over time

Must-haves:

1. Interactive world map where user can select continent to get deeper statistics of waste management in that locale
2. User must have ability to reconfigure mapped data into standard charts
3. Tooltips containing key waste management statistics per country
4. Toggle between map and other visualization components for easy switching

Nice-to-have:

1. When brushing over the scatter-plot data it would be nice if it could highlight the corresponding bar chart data
2. Time-lapse of map showcasing change in waste generation from 2010 to 2025 Ability to zoom in and out of world map
3. Smooth transitions between different visualizations.

All the functions we expect to implement are feasible within the D3 framework, so outside of HTML, CSS and JavaScript we should not need additional libraries or APIs or any server side communication. We may need to use a content delivery network such as bootstrap to get extra features such as seamless page transition animations and other superficial features of the visualization.

7 Visualization Design

Our final visualization design consists of three different components. One component is a world map that shows different plastic metrics per country. The metric will be selected from a set of buttons which the end user can pick which metric they will show. ;In our first visualization, we have shapes as marks since we are visualizing countries. The channels in the first visualization are position, both horizontal and vertical, and color as we wanted to show the different metrics in different colors. This visualization supports the domain tasks which mentions comparing country and continents plastic use. Our second visualization component is a pie chart which shows the plastic waste by economic status, with an option to toggle to show coastal population as well. The marks are shapes (the parts of the pie chart) and the channels are colors, showing the different categories. This visualization corresponds to the domain task that focuses on determining what factors affect plastic waste generation. In the third tab/main visualization, the marks are lines on the bar chart and points on the scatter plot. For the channels, we used both position, horizontal and vertical, and shape. We wanted to show a third attribute on this visualization, so we added the shapes to distinguish economic status. This third visualization supports the domain task about finding projections of mismanaged waste. Both of these visualizations support our data since we visualize most columns in the data in a way that makes sense and so that they are easy to interpret. The bar plot and the scatterplot will be linked together.

8 References

[1] L. Parker. Plastic Pollution Facts and Information. *Environment, National Geographic*, USA, 2021.

9 Appendix A: Group Charter

9.1 Group Purpose

We are all passionate about the environment and want to research more about it. We are going to work together to create a visualization about plastic waste pollution.

9.2 Group Goals

- We all want A's in this course and will work hard to reach a high quality of work.
- We want our visualizations to be useful and easy to understand/use.
- We want to be more comfortable with the different languages and libraries we are going to use in this project.

9.3 Group Member Roles/Responsibilities

- Shivi will be the group leader.
- Elisabeth will be the meeting facilitator and the information manager.
- Ashraf will be the point person for communications and the technical director.
- Justin will be the documentation coordinator.
- We will all communicate and assign new roles if they arise.

9.4 Ground Rules

- We will meet Tuesdays at 2pm in-person in Snell.
  - We will also meet over the weekend if needed over zoom.
- We will listen and respect each other in discussions. Everyone will have a chance to share their thoughts.
  - If people disagree, we will take a vote and decide to move forward from there.
  - Since there are four people, there is the chance for a tie vote and if that occurs we will flip a coin.
  - If someone feels that their voice isn't being heard, we will try to be more aware of that moving forward.
- We expect everyone to communicate on how they are progressing with their tasks and ask for help when needed.
  - If someone has not completed their work, we will ask why and work with them to figure out a better plan moving forward.

9.5 Potential Barriers and Coping Strategies

- One potential barrier is that people will be busy - we hope that people will communicate if they are busy and will not finish their section so that someone else can help them out with the work.
- Group members being unresponsive in the group chat. We will ask questions in the group chat questions and if they do not respond, we will send an individual text.
- A group member is not coming to any meetings without letting the group know ahead of time with a valid reason. We will ask them why and give them a warning. If it is a repeated occurrence, we will let the professor know and ask for advice on what to do.

9.6 Addition to Group Charter

Have you all been abiding by your agreed-upon guidelines?

- Yes, we have been meeting every Tuesday as a group. We all listen and respect each other in our discussions and allow everyone to speak. If anyone needs help on an assignment, they have been communicating this. Everything has been done in a timely manner.

Do you all feel comfortable with the group roles?

- Yes, we are all comfortable with the group roles.

Are there any problems you need to troubleshoot, and if so how can you address them?

- In anticipation of programming project milestones, we worry that meeting on Tuesday will not be enough time to complete the homework. So we will meet on the weekends - a time agreed upon by the Friday before. This way we will have time to troubleshoot and debug if necessary.

Each group member should write one positive thing they have seen other group members contribute to the project.

Shivi:

- Whenever we meet up to go over the next project milestone Justin always contributes in our discussions and comes up with good ideas to work towards our final visualization tool. He took the lead in cleaning our dataset and initially exploring our data, which was very helpful.

Elisabeth:

- Shivi was instrumental in forming our group, as well as creating research questions and domain tasks. Additionally, she has offered me help and helped me with my tasks when I had questions or errors.

Ashraf:

- I think the way Elisabeth has been leading and taking responsibility with tasks has been extremely helpful to the team. She has consistently shown up to meetings, contributed her fair share and is always eager.

Justin:

- Ashraf has taken initiative and has taken the lead in transferring our progress from google docs to our overleaf paper. On top of that, he has been responsive in the chat and has done all of the work assigned to him on time.

10 Appendix B: Data Exploration

10.1 Data Review

After analyzing the data types along with the data values themselves, it was clear that this data set required data cleaning. First, the data types should be all numerical (integer or float) aside from two variables (country and economic status), but eight variables which were supposed to be numerical, were not. Therefore, numerical analyses could not be conducted on these eight categories. Also, when analyzing the values within the table, there were null values and this was because the excel file had a legend for the variables at the bottom along with totals for certain columns, this caused our computers to read those additional rows as part of the data, causing invalid data (the legend and totals) and empty values.

As referenced in the data exploration summary, there were two main issues. One being the data types being read. To solve this, the commas must be removed from the values and then null values must be removed. The null values relate to the second issue with the additional information at the bottom of the data file. To resolve this, the parts of the file that are not part of the data must be removed from the data file itself. This will lead to all the data in the file being valid and would allow our group to conduct the analyses we intended to in order to discover trends and insights.

Data types:

Country	Categorical
Economic status	Categorical
Coastal population	Quantitative
Waste generation rate	Quantitative
% Plastic in waste stream	Quantitative
% inadequately managed waste	Quantitative
% Littered waste	Quantitative
Waste generation [kg/day]	Quantitative
Plastic waste generation [kg/day]	Quantitative
Inadequately managed plastic waste [kg/day]	Quantitative
Plastic waste littered [kg/day]	Quantitative
Mismanaged plastic waste [kg/person/day]	Quantitative
Mismanaged plastic waste in 2010 [tonnes]	Quantitative
Mismanaged plastic waste in 2025 [tonnes]	Quantitative

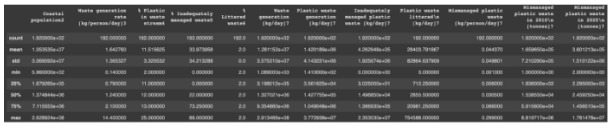


Figure 1: As for the descriptive statistics in relation to the data, one of the more pertinent highlights would be the minimum, maximum and average waste generation rate, which takes into account how many kilograms of waste is generated per person per day. Equally, the minimum, maximum and average mismanaged plastic waste can aid in illustrating to the audience the distribution of waste generation and its subsequent mismanagement.

10.2 Insights

Upon completion of our data exploration some patterns that emerge show that as coastal populations increase so too does the waste generation rate. Another interesting pattern is that the increase in waste generation actually leads to less inadequate management of waste. I think the second pattern is quite interesting because it may be alluding to the fact that more economically developed nations produce more waste but also have more policies in place to deal with the waste versus less economically developed nations.

One issue we found while exploring was how the %littered waste feature only had values of 2 as noted by its maximum and minimum value being the same. In trying to make sense of the data one can only assume that 2.00 is referring to 200% of the waste being littered but the lack of variation in raw data brings to question the legitimacy of these values. Therefore, we will omit this feature in our final data analysis and visualization.

Lastly, something surprising about our data was how it was distributed. All but two of the data-set features had a negative skew. This could be due to the choice of units of measurement.

kilograms per person per day with regards to waste will more than likely result in lower measurements, which can explain the negative skew. Equally the two other data-set features that had a uniform distribution were both using percentages as their unit of measurement. Which lends itself well to a uniform distribution because percentages are uniformly distributed.

10.3 Screenshots

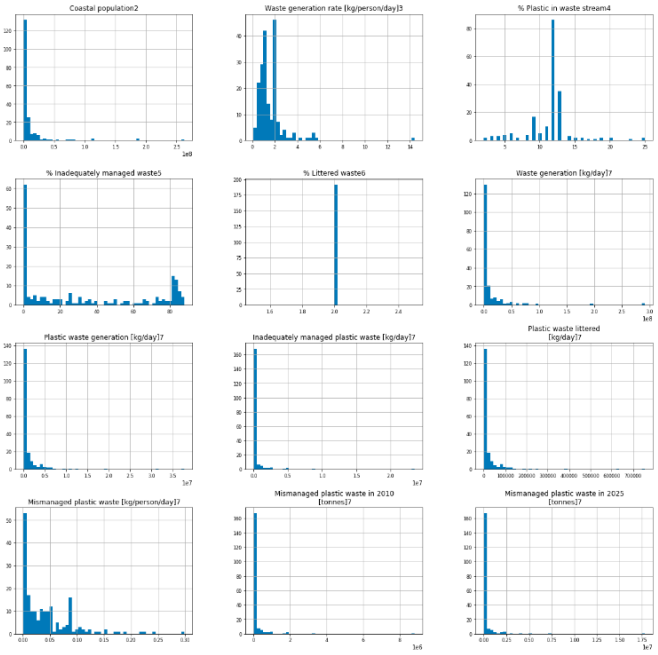


Figure 2: The visualization above shows a histogram of each qualitative metric. The marks we used are lines and the channels we used are position, both horizontal and vertical, and length of the lines. We chose these visual encodings because they make the visualization clear and easy to interpret.This visualization shows distributions of each metric. There is a lot of variation in inadequately managed waste while the waste generation [kg/day] is relatively clumped. The majority of the visualizations are clumped together and close to zero, meaning most countries are handling waste in similar ways.

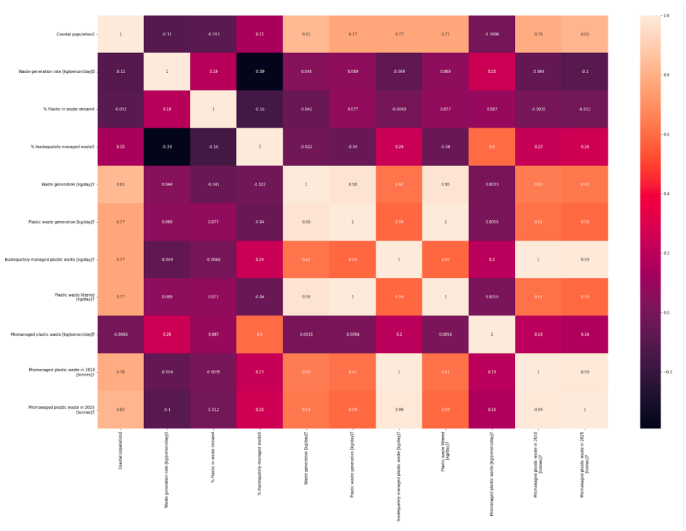


Figure 3: This heat map shows all of the quantitative data in our data set. This visualization shows the correlation between many of our factors. We used color as a channel as our main visual encoding in this visualization because it shows the level of correlation between our metrics. This visualization shows that many of the factors are highly correlated to the size of the coastal population. This makes sense that there will be more waste as the population increases. There are similar metrics, like waste generation and plastic waste generation, that have very high correlation which makes sense since they share similar data.

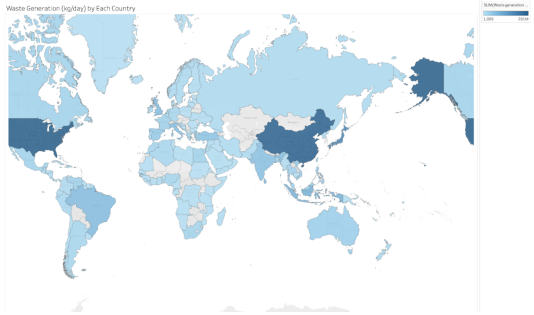


Figure 4: This visualization shows which countries have the highest waste generation in kilograms per day. We used color as the main channel in this visualization because through the use of color it is easy to tell which countries generate the most waste. From this visualization, it can be seen that the US and China have the highest waste generation and all the other countries have a lower level of waste. There does not seem to be a pattern in waste generation.

10.4 Data Snippet

Country	Economic status	Coastal population2	Waste generation rate [kg/person/day]	% Plastic in waste stream4	% inadequately managed waste5	% Littered waste6	Waste generation [kg/day]7	Plastic waste generation [kg/day]7	Inadequately managed plastic waste [kg/day]7	Plastic waste littered [kg/day]7	Mismanaged plastic waste [kg/person/day]7	Mismanaged plastic waste in 2010 [tonnes]7	Mismanaged plastic waste in 2025 [tonnes]7
Albania	UMI	2350533	0.77	9	45	2	1948510	174392	77897	3488	0.032	29705	63051
Algeria8	UMI	16556580	1.2	12	50	2	19867896	2374214	1378695	47484	0.086	520555	1017444
Angola	LMI	3790041	0.48	13	71	2	1819220	235589	166597	4712	0.045	62528	138770
Anguilla	HIC	14561	2.1	12	2	2	30578	3654	68	73	0.01	52	73
Antigua & Barbuda	HIC	66843	5.5	12	0	2	367837	43933	2555	879	0.051	1253	1305

Above is the first 5 rows of the cleaned data set.

11 Appendix C: Interview

11.1 End User Persona

We created our end user persona based on our use case specified in pm-02. In pm-02, we discussed that a potential user would be a policymaker who would use the visualization to help the country

make decisions on how best to reduce waste. While discussing this persona, our group decided that we wanted a more global end user since our dataset has many countries in it. We started looking into the United Nations in order to find an organization that would be related to pollution and we found the Intergovernmental Panel on Climate Change. Then we tried to learn more about the organization and discovered the Working Group III Mitigation of Climate Change and thought that that would be a great place for our end user persona to come from.
Our end user persona is Lynn Smith. She's from the United States and one of the co-chairs of the Working Group III. She has used visualizations before to show trends in average temperature and sea-level rises to see if mitigation measures have been successful. Instead of using visualizations, she spends her time reading papers and attempting to interpret the data from the papers. A visualization tool would help this task because all the data would be in one place and be much clearer and easier to interpret. All the data would be of the same metric and scale and therefore easy to draw conclusions from.

11.2 Interview Script

Interviewer: Hello, please state your name and title
Interviewee: ...
Interviewer: Great nice to meet you, so tell me why are you interested in getting a visualization?
Interviewee: ...
Interviewer: Interesting, and how familiar is your intended audience with interactive visualizations?
Interviewee: ...
Interviewer: Speaking of the audience, what would you say are key characteristics about them that should be considered for this visualization?
Interviewee: ...
Interviewer: Finally with regards to the end users what should they be able to learn, see or do using this visualization?
Interviewee: ...
Interviewer: Great, my last question is will the visualization need filtering capabilities?
Interviewee: ...
Interviewer: Awesome thank you for your time. I look forward to working with you.

11.3 Interview Notes

*** We recorded the mock interview over Zoom so we could go back and listen to the interview again which is why we took minimal notes.

- Lynn Smith with the IPCC
  - Trying to find and show a link between pollution and climate change
  - Mainly works to educate governmental officials about ways to mitigate climate change
  - Wants to pull some compassion out of the government officials
    - But also analytical sides since governments made decisions based on data and research
- After we asked about the characteristics of the audience, we asked a follow up question of: What types of visualization has your audience had prior experience with?
  - Government officials have experience with visualizations before
    - Heat maps and line charts
- Then we added the question: What is the purpose of the visualization? Just to be extra sure we understood the main idea behind the visualization.
  - Purpose is to show how bad the pollution problem is.
- Wants filtering capabilities to be able to get different perspectives on the data

11.4 Interview Results

1. Could you please state your name and title and why you are interested in getting a visualization made?
   - My name is Lynn Smith from the United States and I am one of the Co-chairs of Working Group III Mitigation of climate change in the Intergovernmental Panel on Climate Change (IPCC). I am interested in getting a visualization made because our group is interested in seeing how pollution affects climate change and we would like to see how they are related. Many people do not know that a lot of pollution releases greenhouse gasses because plastic originates from fossil fuels. I would like to visually see what areas in the world are most responsible for this issue based on how much plastic waste they produce and what proportion of it is incorrectly disposed, so we can work towards combating climate change.
2. How familiar is your audience with interactive visualizations?
   - As our audience will be government officials we are educating on how to mitigate climate change, they will have seen their fair share of graphs and visualizations.
3. What are the characteristics of the audience you are trying to attract with this visualization?
   - We want to attract the analytical and also compassionate sides of the government officials so they feel drawn to put more policies in place to help mitigate climate change. Government officials draw their policies from data and research, so the visualization needs sufficient data that shows why this issue must be addressed.
4. What visualization has your audience had prior experience with?
   - In terms of climate change related visualizations, our audience has had experience with line charts and heat maps. The line charts are best used to show trends, like temperature increasing or sea level rising. The heat maps are best used on a global scale to demonstrate what areas are affected more.
5. What is the purpose of this visualization?
   - The purpose of this visualization would be to show the changes in pollution and the severity of the plastic pollution issue. It's important to see how each country plays a part in this issue, and implement the necessary rules and regulations to protect the environment. I want to be able to see what different factors influence plastic pollution. For instance, how a country's GDP affects the amount of plastic that is produced and is sufficiently managed. I want this visualization to increase awareness and serve as call to action for fighting against climate change.
6. As far as the end user is concerned, what should they be able to learn, see or do using this visualization?

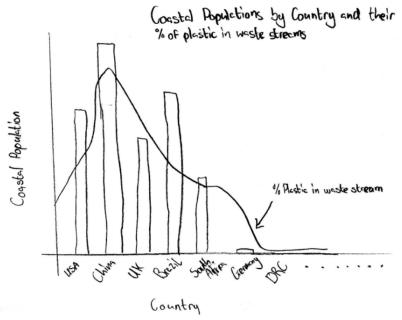
- They should be able to see what areas are most affected by plastic waste pollution and what factors affect pollution. They should see what areas are most responsible for correctly disposing of plastic and which are responsible for littering into oceans.

7. Will the visualization need filtering capabilities?

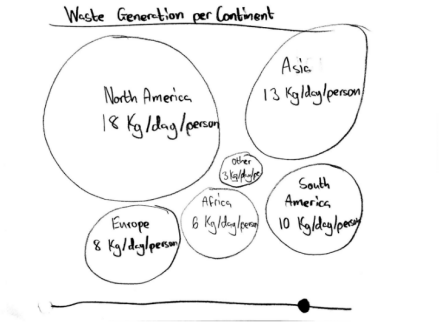
   - Yes, we would like to be able to filter on this visualization. We would like to see how different regions are affected more or less by pollution. In addition, we would like to be able to have different metrics on the visualization we can turn on and off.

12 Appendix D: Design Sketches

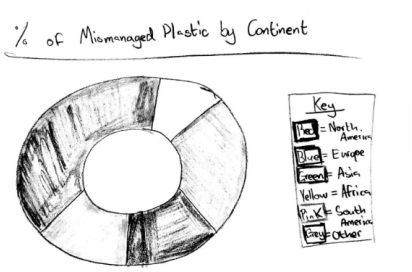
12.1 Individual Sketching



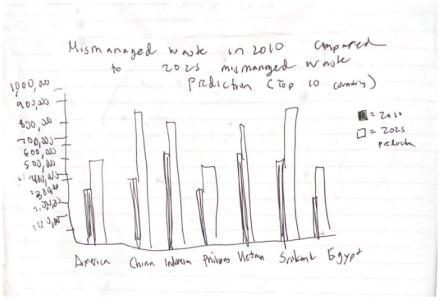
Caption: This visualization was created by Ashraf Bade. For this dataset I have two marks which are bars and lines, and they both use size as a channel. I chose bars to represent the population as it makes it easy to compare two countries and track count data. I chose a line as one of my marks because I wish to express a trend where the higher the coastal population the higher the % of Plastic in waste streams. This visualization is connected to the domain task related to comparing waste metrics of multiple countries and the domain task related to figuring out which factors influence waste generation.



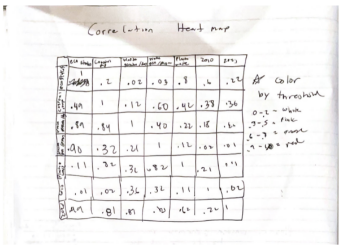
Caption: This visualization was created by Ashraf Bade. For this visualization I chose to use area as the main communication channel to express the magnitude of waste generation. It is the most intuitive translation of the data as the circles are intended to represent crudely drawn trash bags. This visualization is related to the domain task that looks to compare different countries/continent's waste generation.



Caption: This visualization was created by Ashraf Bade. For this visualization the mark is area, meanwhile the channels are angle and color. Where angle represents portions and the color the continent the data is related to. I chose this combination because the data type is a percentage which naturally lends itself well to being displayed as a part of a greater whole. This visualization is connected to the domain task that looks to compare different countries/continents waste management.

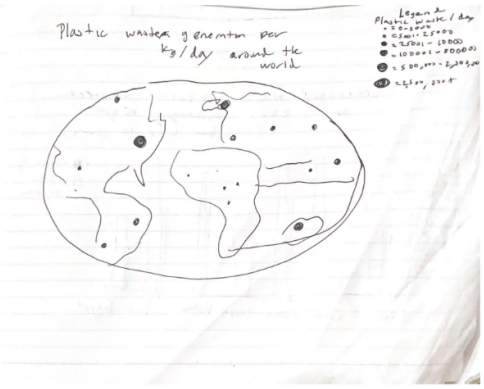


Caption: This sketch was drawn by Justin Woo. The marks used in this visualization were lines and the channels were positions and color. Marks were used since the data being shown is 1 dimensional with mismanaged waste determining the length of the line. Both the horizontal and vertical axes are used in the position of the visuals with horizontal representing country, and as I mentioned before, the vertical representing mismanaged waste. Lastly, color is used to differentiate the 2010 data and the 2025 projections. Color is effective in this case, as it allows the user to easily distinguish the two variables and to be able to compare them. For the visualization choice in general, a group lined chart was used because it effectively displays the comparison of two different variables, so it is a great fit to compare 2010 data and 2025 predictions. Lastly, This addresses the domain task that wants to analyze the projections and compare the mismanaged waste for each country

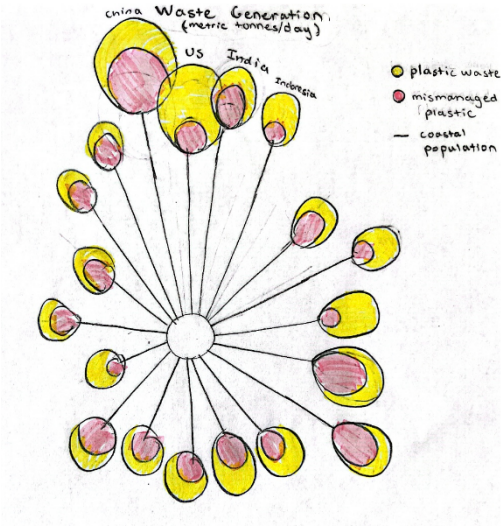


Caption: This sketch was drawn by Justin Woo. The marks used were points and the channels were position and color. Position represents both horizontal and vertical axes with both axes being all of the variables. Color represents the value of the correlation in each cell, with higher numbers being closer to red and values closer to 0 being white. I forgot to include negative values, but numbers approaching -1 will approach blue. Points were chosen because the

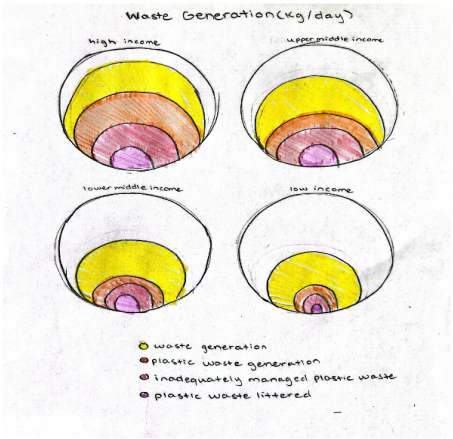
data represented by them are 0 dimensional, as they are just cells within a table. Color was utilized to represent the correlation, as it is easy to interpret and is the only channel that works within a table. The visual was chosen because heat maps are effective in including correlation calculations between every variable. It allows for easy understanding, but if there are too many variables, it does become chaotic for the viewer. Lastly, This addresses the domain task that wants to identify the main factors in waste generation.



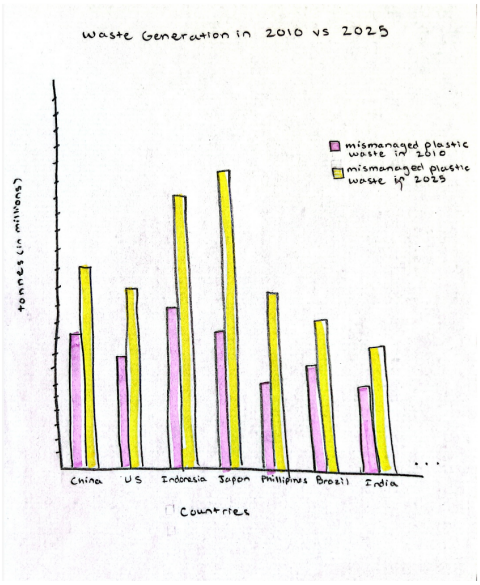
(FAVORITE)
Caption: This sketch was drawn by Justin Woo. The marks used were points and the channels were position and size. Position represents both horizontal and vertical axes, as it represents the location of a country on the map, while size represents the plastic waste per day for the particular point (the bigger the point, the more waste per day). Points were chosen because the data represented by them are 0 dimensional, as they are just elements to show location. Position was chosen for location as well, but size (area) was utilized because the data values are a range of continuous values and I believe size is the easiest to interpret in this scenario. The visual itself of the map was chosen to allow users to easily visualize each country/ continent included in the data; without seeing the labels, the user is likely able to know what certain countries are. This sketch addresses the domain task that wants to compare two different countries/continents with their plastic waste metrics



(FAVORITE)
Caption: This visualization was drawn by Shivi Sood. The marks are areas and lines. The channels include size (the greater the area of the circles the greater of the corresponding metric, the greater the length of the line the greater the coastal population) and color (to distinguish each of the plastic waste metrics). I chose to represent the metrics through size as it would be easy for the user to visually see what metrics are greater than others through the size of the circles and the length of the lines. This visualization addresses the domain task of comparing different countries' waste metrics. It accomplishes that through including different waste metrics in the circle that are easy to understand since each metric is distinguished by a different color. Also allows the user to identify which countries have a greater coastal population that may be contributing to greater plastic waste littered in streams.

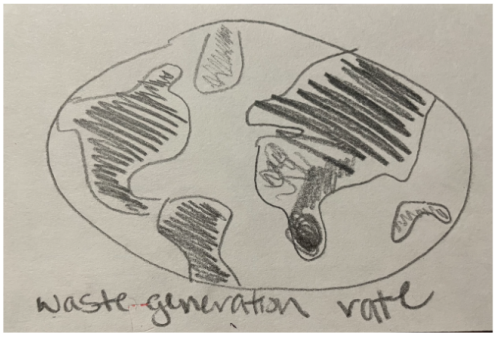


Caption: This visualization was drawn by Shivi Sood. The marks used were areas. The channels include size (the greater the area of the circles the greater of the corresponding metric) and color (to distinguish each of the plastic waste metrics). I chose to represent the metrics through size as it would be easy for the user to visually see what metrics are greater than others. The end user wants to assess how economic status affects waste generation. They want to see if it's true that lower income countries have more mismanaged waste, while higher income countries have greater waste generation to implement policies for each country accordingly. This visualization accomplishes that through showing four different economic statuses and showing the averages of four different plastic waste metrics for each status.

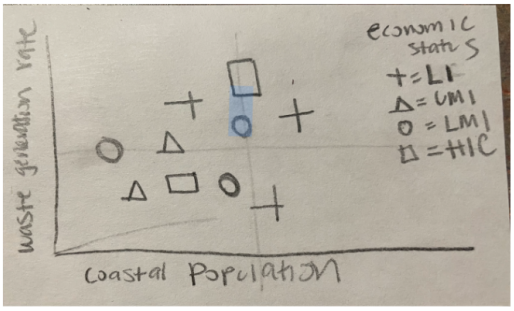


(FAVORITE)
Caption: This visualization was drawn by Shivi Sood. The marks

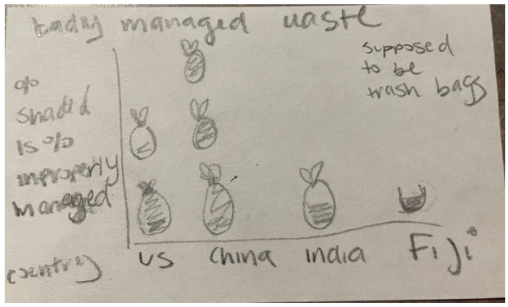
used were lines. The channels include position (both horizontal and vertical variables on axes) and color (to distinguish the years). I chose to represent the projections as a double bar graph with each country on the horizontal axis and the mismanaged plastic waste on the vertical axis to compare between the current year and the projected year. This visualization addresses the domain task to analyze the mismanaged plastic waste generation for each country and compare that from the present to the projected year. This visualization accomplishes that through having a double bar graph for 2010 and 2025 so the user can compare plastic waste generation from both years.



Caption: This visualization was drawn by Elisabeth Leung. For this visualization, I have used areas as the marks and I have used color (shading for black and white) as a channel to show the differences in the waste generation rate based on each country shown on a map. I chose these because it would be easiest to see the different rates through different colors and I chose to use shapes to create a map so that it is simple to compare different rates. This visualization connects to the domain task that is "I want to be able to show my team the comparison between two different countries or continents with their plastic waste metrics". Using a map, it is easy to compare different plastic waste metrics per country or trends per continent because everything is one area and they are all close together.

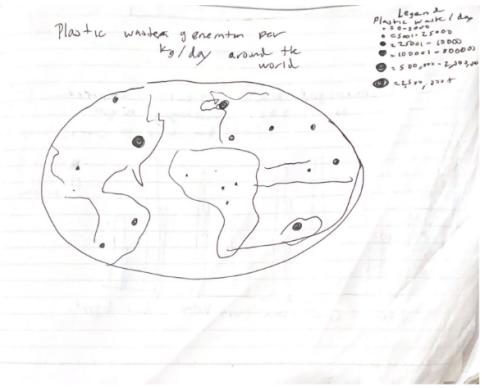


Caption: This visualization was drawn by Elisabeth Leung. For this visualization, I used points as the marks. I chose points because I wanted each country to be shown and to be distinguished from each other. Additionally, each country has two different values, so there was no way for them to be grouped together. For the channels, I used both position, horizontal and vertical, and shape. I wanted to show a third attribute on this visualization, so I added the shapes to distinguish economic status. This visualization connects to the domain task "I want to identify the main factors in waste generation in order to prioritize the teams plan to reduce it" because there are different factors being graphed in this visualization and the users will be able to see if coastal population and economic status have an effect on the waste generation rate per day.

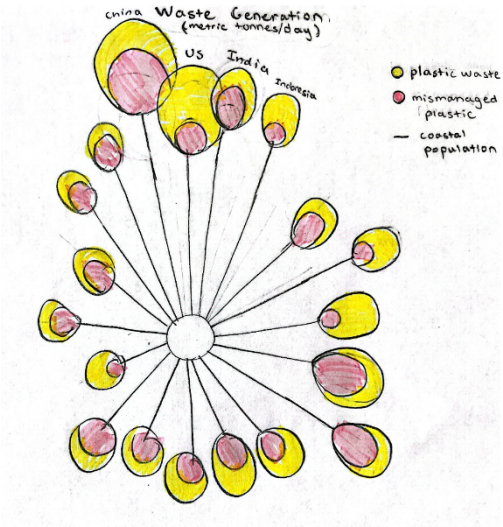


Caption: This visualization was drawn by Elisabeth Leung. For this visualization, I chose to use shape as the marks. I wanted to use the trash bags shape and lines to symbolize the pollution since pollution is trash. For channels, I chose to use the position of the bars to compare the level of pollution and color to show the percent of trash that is mismanaged. This visualization is connected to the domain task that looks to compare different countries/continents waste management. It will show how different countries compare to each other in terms of their mismanaged waste.

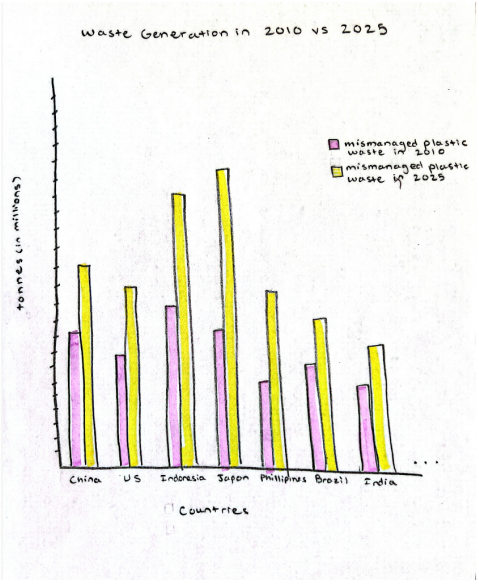
12.2 Group Selection



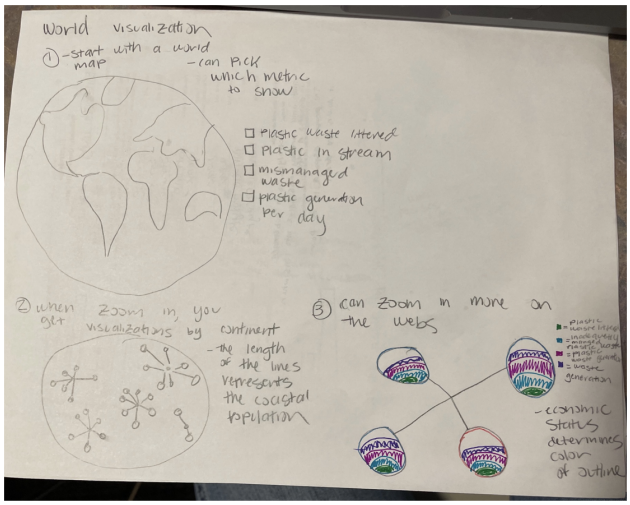
When looking over the 12 visualizations that our group drafted, there were a few things we used to evaluate and compare them to narrow it down to only 3. Firstly, we wanted visualizations that are flexible in the number of dimensions that can be implemented while maintaining its readability to the user. Next, we wanted to choose visualizations that are able to compliment each other to add flexibility of combining them. And lastly, they need to effectively satisfy one of our domain tasks. The first visual we selected was the map of the world that is able to display a waste metric either on a continent level or a country level. The domain task that this relates to is the comparison of countries/continents. This visual supports all of the quantitative data types in our data set and only the countries as supported categorical values. This is an effective visualization because it clearly depicts the country/continent of each data point based on the map even without the use of labels, and with the use of point size, it effectively portrays the volume of the waste metric selected. For the user to see the name of the country, they would hover over the desired point.

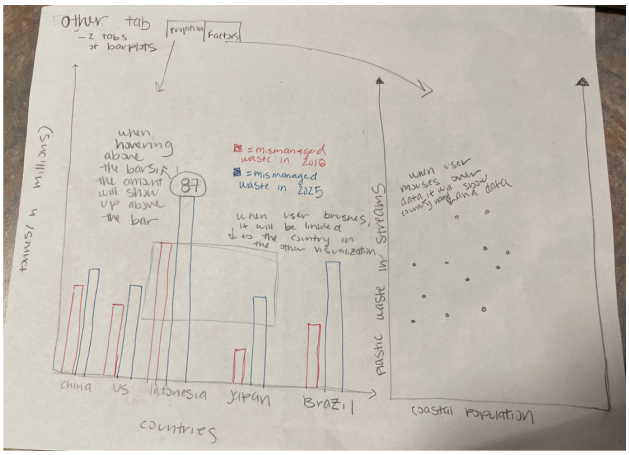


The next visual we selected was this spider web visualization. This was selected because it is able to present 4 different variables at the same time while still maintaining readability. The domain task that this relates to is to also compare the waste metrics from different countries to one another. This visual also supports all of the quantitative data types in our data set and only countries as supported categorical values. The layered circles and the lines are easy to understand and readable for the user and are able to present a lot of data at once.



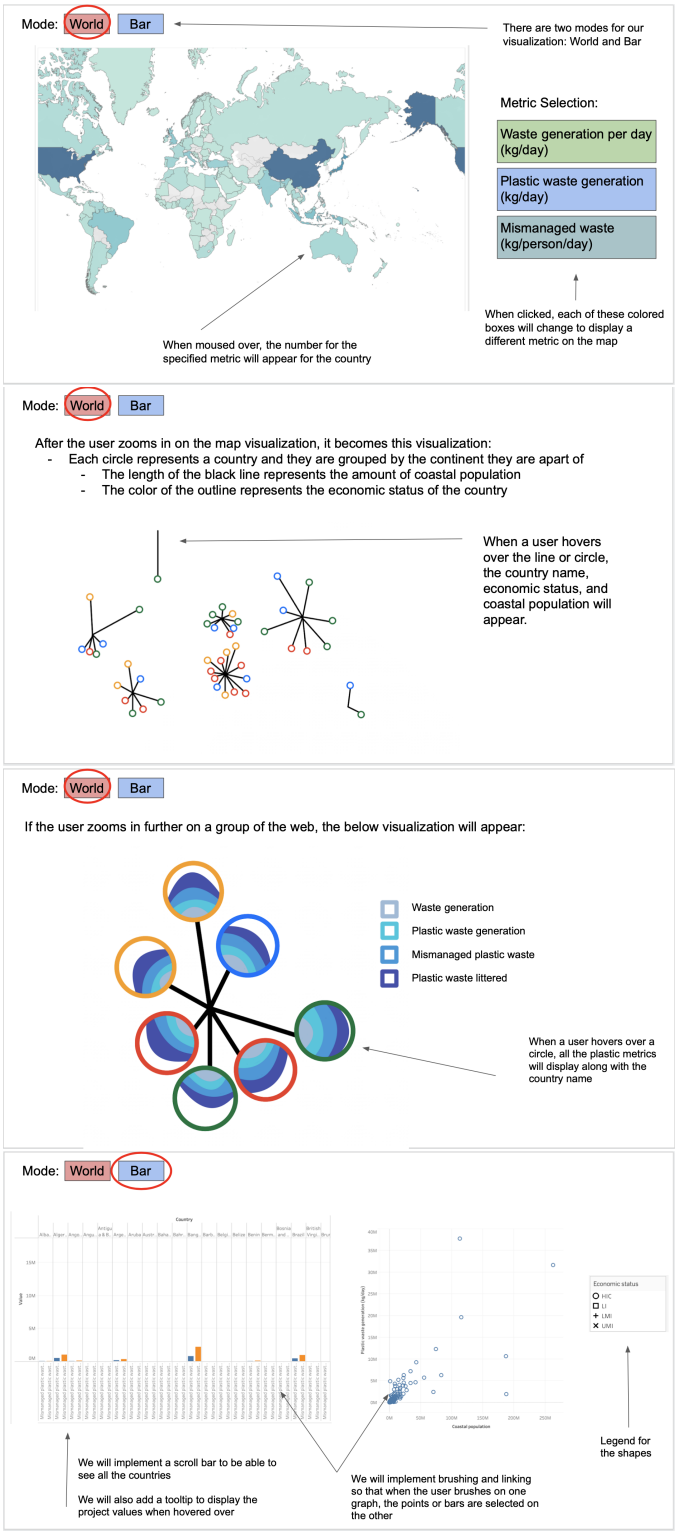
The final visualization that was selected was a grouped bar chart. This tackles our domain task that evaluates current and future mismanaged waste for each country. This visual also supports all of the quantitative data types in our data set and only countries as supported categorical values. This grouped bar chart is very simple, yet effective, as the projections can be easily compared to the current waste numbers for all countries.





Our final sketch consists of two main visualizations. One visualization starts with a world map view and as the user continues to zoom in, there are two different visualizations that appear. The first one is of the metrics in continents and the second compares plastic metrics across countries. The other visualization consists of two plots: one bar plot which shows the 2010 and projected 2025 mismanaged plastic waste values and one scatter plot which shows coastal population and economic status plotted with plastic waste generation. In our first visualization, we have lines and shapes as marks since we are showing coastal population as a length and also visualizing different pollution metrics as parts of a circle. The channels in the first visualization are position, both horizontal and vertical, and color as we wanted to show the different metrics in different colors. This visualization supports the domain tasks which mention comparing country and continents plastic use as well as the task which focuses on finding which metrics contribute to plastic waste (using the lines and circles in the zoomed in visualization). In the second tab/main visualization, the marks are lines on the bar chart and points on the scatter plot. For the channels, we used both position, horizontal and vertical, and shape. We wanted to show a third attribute on this visualization, so we added the shapes to distinguish economic status. This second visualization supports the domain task about identifying the main factors in waste generation and also the domain task about finding projections of mismanaged waste. Both of these visualizations support our data since we visualize most columns in the data in a way that makes sense and so that they are easy to interpret.

13 Appendix E: Digital Sketch



In our visualization we want to start with a world view. We want to give the user the ability to click on different countries or continents to see different waste metrics including total waste, total plastic waste, total mismanaged waste, and total littered waste by each country. This would address our domain task of comparing different countries or continents based on their waste metrics to help the end user be more aware of which countries are big contributors to the plastic waste issue. From the world view, we want to be able to show a spiderweb visual for each continent. Each country has their own circle in which the size of the circle represents the total plastic waste. Within each circle there are 3 other plastic waste metrics in which their magnitude is represented by the size of their circles. The length of the lines attached to the circles in the spiderweb indicates each country's coastal population. The country's circle outline is based on economic status. This spiderweb visualization addresses the domain task of wanting to access different waste metrics, while also seeing how different factors affect waste generation to work towards reducing them. Finally,we want to include another tab with projections of mismanaged waste. This will be represented by a double bar bar plot to show the 2010 and 2025 mismanaged waste levels for each country. There will also be a bar plot that has different factors (coastal population, economic status) to see relationships between them and the plastic waste generation per day. This addresses the domain task of wanting to see how each country's projected mismanaged waste compares with their current plastic waste in order that they can work towards implementing strategies to reduce the amount of plastic waste.

In drafting a combined sketch for our visualization, we looked back at our domain tasks and assessed which ones our visualization would fulfill and made changes accordingly. We decided to change one of our domain tasks about the comparison between two different countries to also include continents for the user to be able to also compare waste metrics between continents since policy makers may want to implement policies by each continent. We also changed one of our domain tasks completely to visualize mismanaged waste projections, so we can try to implement strategies to reduce the amount of plastic waste for the future.

14 Appendix F: Usability Testing

Brainstorming Usability Tasks: I want the other group viewing our visualization to see the difference between two countries or continents through our map visualization. I want them to see which countries/continents are actively contributing to the plastic waste problem and managing their plastic waste sufficiently to reduce the issue. I want to see what factors impact waste generation. Currently, our map shows the waste generation for each country, but we would like it to show other metrics related to plastic waste as well, including specifically plastic waste generation, mismanaged plastic waste, and plastic waste litter, and allow them to compare by filtering on these different metrics. Using the pie chart, the group should also be able to identify the main factors in waste generation by viewing our pie charts that show how the four different economic statuses influence waste generation.There is also a scatter plot which shows the relationship between waste generation and coastal population. Finally, we would like to present projections for the future of the sum of mismanaged plastic waste by each continent in 2025 compared to 2010.

14.1 Preparation

Other group: Hello! Can you please tell me a little about your visualization and its intended use?
Our group: Our visualization tool is intended to show the severity of the plastic waste pollution problem globally by highlighting several plastic waste metrics and the factors that influence waste generation. The visualization would be beneficial for a policymaker to identify which countries are most responsible for prolonging plastic pollution, so they can best implement strategies to reduce the severity of the problem.
Other group: Great! What data or metrics will you use to show this?
Our group: The key metrics we want to focus on for each country are total waste generation, plastic waste generation, inadequately

managed plastic waste, and plastic waste littered.
Other group: What are some tasks we could accomplish through using your visualization?
Our group: The three main tasks our visualization tool accomplishes is that it will allow the user to visually see and compare several plastic pollution waste metrics for each country, identify the most responsible factors for waste generation, and view each country's mismanaged plastic waste forecasts in comparison to their current waste.
Other group: Great! Do you think for each of these tasks you could explain why you are testing them and the expected outcomes?
Our group: We are accessing plastic waste metrics for each country by showing a heat map. We believe it would benefit our end-user to identify which countries are the main contributors to plastic waste pollution. As a result, it would allow policymakers who view our visualization to put in place strategies in these countries to reduce overall waste production, encourage better waste management systems, and recycling or reuse of plastic. Also, we want our intended audience to be able to access whether certain variables actually affect the different plastic waste metrics through viewing the correlation between these two variables. Identifying factors such as economic status and coastal population and their effect on waste generation will allow the user to analyze what variables are correlated with greater waste production. For example, if there's a trend that lower-income countries have a higher amount of mismanaged plastic waste and incorrectly dispose of it, then more stringent policies can be put in place for countries that fall within this economic status. Identifying this relationship would be very beneficial to our overall purpose of helping our end-user identify ways they can aid the plastic pollution problem. Lastly, we must test the visualization's ability to project the amount of mismanaged waste into the future, so we can understand the scope of the problem in the future. If there is a significant amount of increase of the amount of mismanaged plastic from 2010 to 2025, this would signal to our end-user that action must be taken immediately to encourage individuals to not litter and recycle more so there is less mismanaged waste by 2025.
Other group: Sounds good, thank you for your time.

14.2 Results

Overall, we did not have any major issues. We had a couple minor issues. One is that our visualizations were not arranged on the website in a coordinating way. This is to say that it was hard to use visualizations at the same time since the two that were related were not near to each other on the page. A minor issue was that our map visualization was off centered and users had to scroll to see the tooltip and the legend. The participants liked the scatter plot and its interaction and they thought the map idea was good.

One of our tasks was for users to visually see and compare several plastic pollution waste metrics for each country. Our tool was very effective in visualizing countries and their metrics with maps and that the color coding with the legend is very clear. There were a couple issues while tested.The position of the visualization is too far to the right, so to see the legend, you must scroll to see it. Additionally, the tooltip was incomplete in the fact that it only shows Russia. Our metric that we were looking for was if the participant had the ability to evaluate metrics on the basis of countries without confusion. From our test results, we will revise the orientation of our visualizations so everything is within view and utilizing space effectively. Also, we also did not complete the full implementation of the tooltip for this map visualization, so that will be worked on as well.

Our second task was to identify which economic status per country would produce the most waste per person. Our choice of the pie chart allowed for this task to be very easily fulfilled, with each piece of the pie representing one of the four economic statuses. In regards to what outcomes we expected from this task, we expected the user to have the ability to quickly and easily determine which economic status was most influential on the waste per person. The status that produced the most waste per person was pretty clear with our specific data, but, if it wasn't so clear and the top two statuses had very similar values, this is where the drawback of our visualization comes into play. We did not include any percentages or actual values during this test. We intended to add either data labels or a tooltip to reveal the percent and value of each variable, but we had not implemented that yet.

The final task was to compare the current waste metrics to the projections for each continent. This task caused the most issues out of the three tasks. The main reason for this was the wording of the task, as we instructed the user to compare "current" waste metrics with projections and although the grouped bar chart was a great choice of a visualization for this task, the data itself didn't align with it. We failed to inform the user that the data source provided us with data from 2010, which is far from current. This caused the users to not be able to reach the outcome we desired due to the misinterpretation of the task. The results of this test definitely indicate that a change to the task itself is necessary. It needs to be clarified that the data is pulled from just past 2010 rather than up to date.

We plan to add different tabs in our visualization which will help the end user navigate through our visualization's different views. This way, it will be easier and make more sense to the user instead of all the visualizations on one page. Additionally, we plan to move the scatter plot next to the grouped bar chart so it is easier to compare the different aspects of mismanaged waste. The scatterplot and the grouped bar chart show similar plastic waste generation, so it would be easier to compare the two visualizations if they are next to each other. We also plan to fix the tooltip on the map so that is is accurate for each country. This is because we want to have accurate information.