Plastic Waste Management System

Solomon Durgam, Ashwik Kilari, Seelam Chaitanya, Jonah Ukaegbu, Namratha Siddula

Abstract—Our motivation comes from the present world's burning situation, Environmental pollution caused due to usage of plastic that has rendered our way of life unsustainable. So, we have analyzed the Plastic Waste dataset that contains information about the Plastic Waste generated by different Countries across the world in the years 2010 and 2025. Using this data we want the reader to compare correlations, find the dependencies and summarize trends of Plastic waste generated and also, be able to present distributions to other users to get a better comprehension of the world and the detrimental effects of plastic on the nature due to the release of harmful gasses into the atmosphere.We want the user to know the distribution of plastic waste generated from each region, compare mismanagement by different countries through two different years 2010 and 2025, and understand contribution of plastic waste in different forms to the total plastic waste generated by all the countries around the world. Our main target would be governmental, not-for-profit, and public users who could leverage this information and aim up the efforts in an effective manner to save the environment. In the previous research the authors have emphasized more on the inadequately managed plastic waste and GDP per capita of that country which we think would be difficult for the users to understand and also they have used bar chart to visually represent this data for each country which makes it difficult to get the overview and adds cognitive load on the users when they have to compare between two different countries, so to address this issue we have implemented the overview by making use of Map plot which takes geospatial data to represent it in a way easier for the users to understand. We were able to validate the results that we achieved by using peer reviews , consulted the expert opinion and by conducting a survey for effectiveness of visualizations for the specific user tasks. The full system is found at: https://public.tableau.com/app/profile/solomon.jayakar.durgam/viz/DataVisProj_Assignment3/DashboardExpFinalBeta-PhaseRelease

Index Terms— Visualization, Tableau, Pie Charts, Bar Graphs, Geographical Maps.

1 Introduction

Our Project domain defines one of the Environmental issues that is plastic waste generated all over the world. The users of our visualizations would be the governmental, not-for-profit and public users who can consume it to make efforts to save the environment. We want these users to perform certain sets of {action, target} pairs for every user task on our plastic waste dataset. Those are as follows, User Task 1: the users should be able to {present, distribution} summary of the amount of plastic waste generated by different countries around the world. User Task 2: the user should be able to {Summarize, Trends} of mismanaged plastic waste by each country in the years 2010 and 2025. User Task 3: users should be able to {present, distribution} Contribution of different forms Plastic Waste to Total Plastic Waste generated by different countries across the world. Most of previous research done using this dataset only talks about the GDP per capita and the inadequately managed plastic waste but we would like the users to analyze the amount of plastic that is generated by each country and the trends of how the mismanagement would be from 2010 to 2025 and get the general idea of whether there is an increase or a decrease in the amount of plastic waste that is generated and mismanaged, this could really help the users to reduce the amount of plastic generation that would in-turn decrease the mismanagement of plastic and helps in saving the Environmental health.

Our dataset, [1] Plastic waste data is in tabular format with 192 items and 14 attributes that provide useful information regarding Mismanaged plastic waste in 2010 and 2025 in metric tons, waste generated, plastic waste generated in kg/day and also gives useful information about plastic waste generated from different forms. Using this we can answer some crucial question such as “Amount of plastic waste generated in one country to another ”, “How much amount of plastic waste was mismanaged in the years 2010 and 2025 (projected) by different countries across the world” and “What is the Contribution of different forms Plastic Waste to Total Plastic Waste generated”. These datasets are generally collected using various sources such as World Bank estimates, U.S national litter study and also some of the data is generated or calculated using the models for that specific project. In our dataset the column names Waste generation, Plastic waste generation, Inadequately managed plastic waste,Plastic waste littered, Mismanaged plastic waste, Mismanaged plastic waste in 2010, Mismanaged plastic waste in 2025 are calculated fields. There are certain limitation to this dataset, it does not clearly give the information of each of the fields that are part of the dataset and also while creating visualization for user task 3 we faced an issue in Tableau [2] while using this dataset as it does not provide the associative relationship between the

different fields of our dataset this made it difficult to generate part to whole contribution pie chart since Tableau was unable to find the relation between the fields to find the part to whole contribution. To overcome this we have transposed the data by changing the dataset rows to columns and this has created an associative relationship between the fields using the country field and we were able to generate the visualization for our user task 3. To implement all our visualization we have used Tableau Public which is a free version that is available to download and use. We have mainly used 3 idioms: Map plot, Bar plot and Pie chart for our user tasks. For our user task 2 we have added interactivity to our Map plot that could help users to select and filter the countries of their interest and compare between them for the 3 user tasks that we have created. This interactivity addresses the issues of having cognitive load on users of remembering the values on the plot that does not fully fit in the screen and requires the users to scroll to find and compare the different countries of interest, which the previous research studies were not able to provide to the users. We have also compared and contrasted between different idioms that we used to represent the same user task and its effectiveness. Overall we want to help the user to understand the growth in plastic waste and understand the importance of reducing the plastic waste generation to help save the Environment.

2 Related Work

S.L. Wong, et al. [3] describes about Marine pollution from the year 2009 to 2019 (A Bibliometric analysis) and its effects caused to the food web and the environment. There are several precautionary measures that need to be taken as the plastic waste pollution causes severe damage to the environment and affects daily life.It continues to talk about a few journals that they have collected and analyzed to visualize the amount of plastic waste that is affecting the food web in each country using the area as marks and saturation as channels in the geographical map as shown in Fig.1. and also, created a pie chart to show the percentage of review papers that were studied with respect to Microplastics and Nanoplastics in aquatic food web, terrestrial food web and food for human consumption. We will be using a similar approach while representing the data using the marks as area and channels as saturation but we will differentiate by showing the different types of plastic waste that is being generated in each country. Also, we have created a dashboard to show different kinds of plastic wastes and their contributions to total plastic waste generated that is easily understood by the users.

G.-C. Grün et al. [4] summarizes where the plastic originates from and how it ends up and depicts the production of plastic from 1950 to 2014, as well as the use of plastic in various ways and how it is disposed of. It also discusses potential solutions to reduce the use of plastic and also mentions countries that have enacted laws governing the production and sale of plastic.

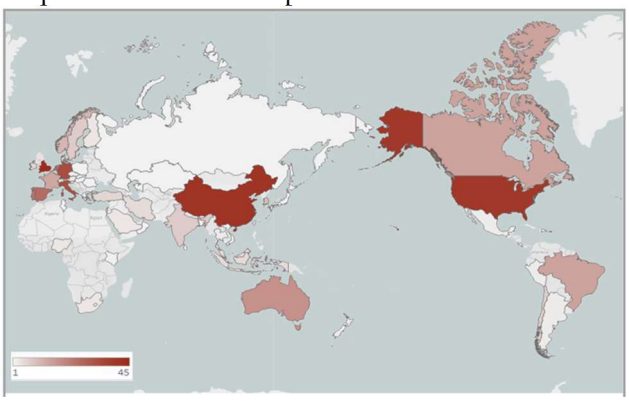

Fig. 1. Amount of Nano and Micro Plastic Waste generated by each Country. Based on Plastic Waste data available, the geographical map summarizes the amount of Nano and Micro Plastic Waste generated by each Country across the map which affects the global food web.The color variations define the different categories - the darker the color the Micro Plastic Waste generated and the lighter colors the Nano plastic waste. This figure replicated from [2].

When it comes to visualizing the data, they used a variety of idioms, such as bar charts to show global plastic output over time, and pie charts to show plastic usage in various forms. They also used idioms to inform the target audience about the use of plastic by various nations over time and the plastic laws that were in place.

The case study only displayed global production in specific years, not each country's contribution or trends over time, so we in our visualization want to represent the total plastic waste generated by each country and let the target users know plastic waste that is produced by each country using a geographic map.

E G Shershneva et al. [5] is “Plastic Waste: Global Impact and Ways to Reduce Environmental Harm”, talks about the harmful effect of using plastic and the increase in plastic usage in different sectors of production over the years from 1950 to 2015, depicted in Fig. 2. The distribution of plastic waste generated per day in kilograms is presented using the map plot, shown in Fig. 3. The major questions answered by using these visualizations are, “What is the contribution from each sector of industry”, “Is plastic usage increasing or decreasing over the years across the different sectors”, and “What is the distribution of plastic waste generation across the world”. The {action, target} pairs that are emphasized are {discover, distribution}, {present, trends} as discussed above. Our approach is similar to this paper [5] while using the map idiom, but we have represented the total plastic waste generated by each country instead of the country’s per day generation and we have added the labels to show the numeric value on the map to make it easier for the user to understand and compare the distributions of plastic waste generated in each country instead of just color coding the bins based on total plastic produced by a country represented on the map.

L. Lebreton et al. [6] is "Future scenarios of global plastic waste generation and disposal", uses vis to discover the distribution percentage of plastic mismanaged vs. total plastic generated and total land surface area vs. total modeled surface represented by a paired column idiom, shown in Fig. 4. We have used a different approach to represent the distribution percentage of plastic waste generated of the total waste generated. Users might not understand the meaning of the term total modeled surface area and the visualization does not provide much information to the users as the values are all modeled and calculated projections up to the year 2060; instead, we made it simpler for the users to understand the basic percentage of mismanaged plastic vs. plastic generated and created an interactive dashboard to deep dive into the country-specific information about waste generated per day and its mismanagement.

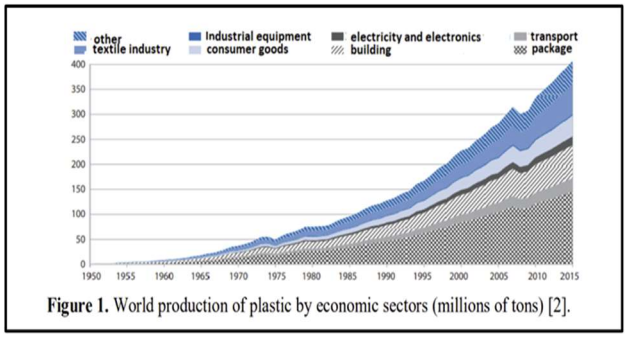

Fig. 2. Plastic produced by different economic sectors over the years from 1950 through 2015, the area plot shows the increase in plastic production from 1950 to 2015 with different economic sectors represented by color and pattern. The plastic production has increased from a value close to 0 million tons in 1950 to close to 40 0 million tons in 2015. This figure replicated from [5] .

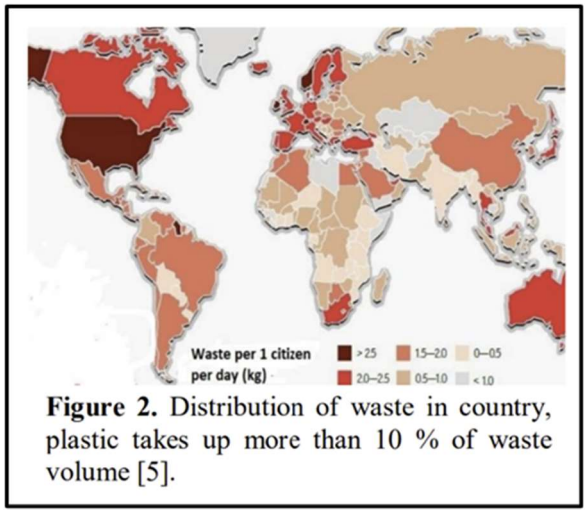

Fig. 3. Distribution of plastic waste in the country takes up more than 10% of waste. The amount of waste produced per citizen per day in kg is divided into bins and the data is presented using a Map plot. Here the top producers are North America, Europe, Australia and China. This figure replicated from [5].

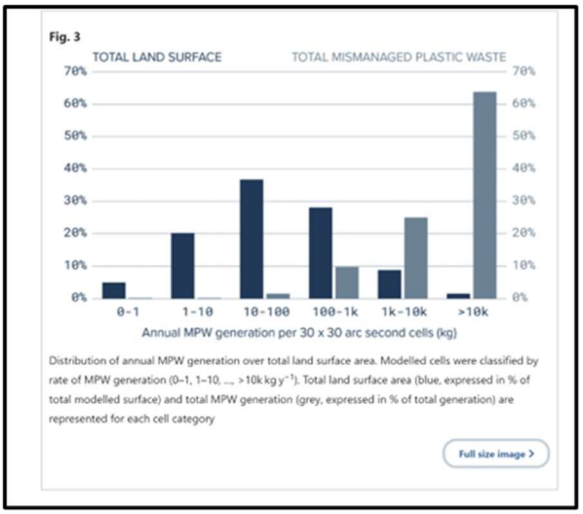

Fig. 4. Distribution of Mismanaged Plastic Waste generated annually over total land surface area modeled. The mismanaged plastic waste generated is modeled into different bins using the rate of generation and expressed in percentage of total generation.This figure replicated from [6]

J. Royle et al. [7] demonstrates the Plastic Drawdown approach that can be used to investigate the significance of different plastic waste flows, clearly visualize a country's plastic pollution challenge, investigate the potential effectiveness of the different policy instruments available to decision makers, and monitor change over time. Our paper takes into consideration the world's data but the case study taken here is only limited only to Maldives. With this constrained data, it highlights strategies with the potential to reduce leakage of plastic waste into the marine environment by up to 85% by 2030.

H. Ritchie et al. [8] details on how the production of plastic has increased in recent years. It goes into how one of the reasons is because plastic is almost everywhere in our daily lives, from food, lotion, medicine, water, etc. Our approach is similar to this [8] journal as it also goes into detail about the amount of plastic in our natural environment, in particular how plastic is affecting the pollution in the air and having a negative impact. But differing from our approach , the figure does go into detail on how exactly the amount of waste mismanaged on a global scale. But our approach is we want to highlight other parts of the world but also emphasize that where we live is also being heavily affected by mismanaged waste. The author tries to have the readers understand how plastic waste has harmed the environment by displaying a visualization of a world map similar to Fig. 3. to showcase the amount of plastic waste being emitted to the ocean per capita, in 2019. The map itself is interactive and allows you to hover over a country and it gives an estimate on how much the average person emits plastic in the ocean and also emphasize on which countries are the worst for producing plastic waste using color with a hue of red. This information can also be viewed in table or chart format for better understanding. It may not explicitly say that its intended audience is the government, in particular the people in a higher power, but it does present this to the audience on what is happening and bringing awareness.

A. Overview of the methodology

Our project methodology involved using the programming language Python to clean our dataset and create the required visualizations for the user tasks that we designed using the tool Tableau Public.

B. Complete methodology

We have performed data cleaning on our dataset by removing the rows that contain null values and unrelated text in python and exported the cleaned dataset to excel. Once the data cleaning was done we have worked in tableau to create the data visualizations for our defined user tasks to address 3 main questions: "How much of the plastic waste is produced by each of the countries across the world", "How much amount of plastic waste was mismanaged in the years 2010 and 2025 (projected) by different countries across the world" and "What is the contribution of Plastic waste generated in different forms of waste to the total waste generated". For each of these user tasks we have designed our visualization using different idioms in the tool Tableau Public and compared each one of them to figure out the best suited idiom for that specific user task.

User Task 1

For the user task one of providing the summary of the amount of plastic waste generated by different countries across the world, the {action , target} pair would be that the user will be able to {present , distribution} of plastic waste generated by different countries. There were a couple of options we came up with to provide the summary view using the idioms such as Bar Plot, Heat Map and Map Plot. Each of these has a drawback that helped us make a decision on finalizing a visualization to represent our user task one.

Option 1: Bar Plot

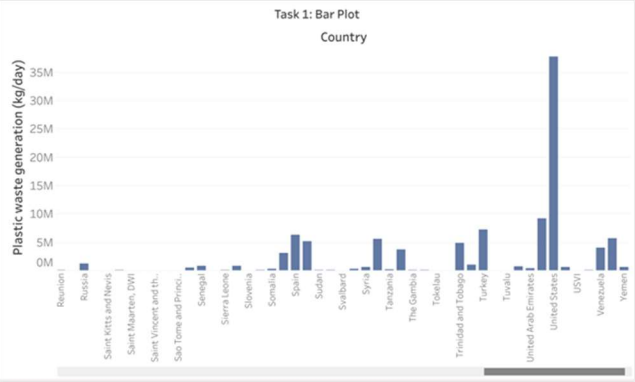

Fig. 5. Amount of Plastic Waste generated by each Country. Based on Plastic Waste data available, each bar in the Bar Plot represents a Country and the length of each bar represents the amount of Plastic Waste produced in tons by that country. Out of all countries, the United States is the highest producer of plastic waste based on the available data.

We have created a Bar Plot as shown in Fig. 5. to present the summary distribution of plastic waste generated by each country using the line as marks to represent the amount of plastic waste generated. Using this bar plot, users can easily find the highest and the lowest amount of plastic waste producing country by looking at the height of the bar but since it does not fit all the information on the screen and requires the users to scroll to find a country they are looking for can be a tedious job, so we have left out this option.

Option 2: Tree Map

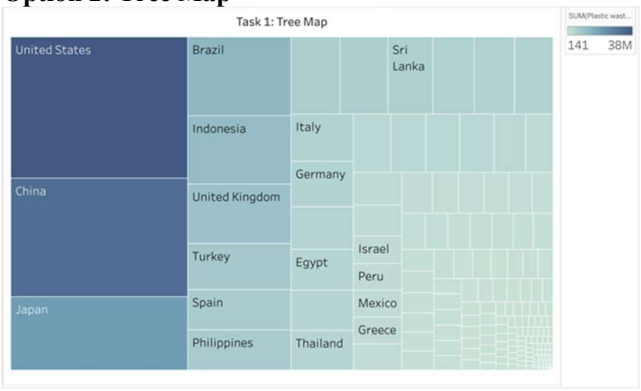

Fig. 6. Amount of Plastic Waste generated by each Country. Based on Plastic Waste data available, the size of each rectangle represents the waste generated by that Country and the color represents the quantity of Plastic Waste generated. The United States takes the top place with the dark blue color based on its per day Plastic Waste generation.

We have created a Tree map as shown in Fig. 6. as our second choice to represent the overview, and it could help the users to easily identify the country producing the highest and lowest and also it is ordered from maximum to minimum. The amount of plastic waste generated is represented with the mark as area of the box. The downside of using treemap is that the lowest producing Country's name is not clearly visible due to less available area and it becomes difficult to understand when there are too many countries to display.

Option 3: Map Plot

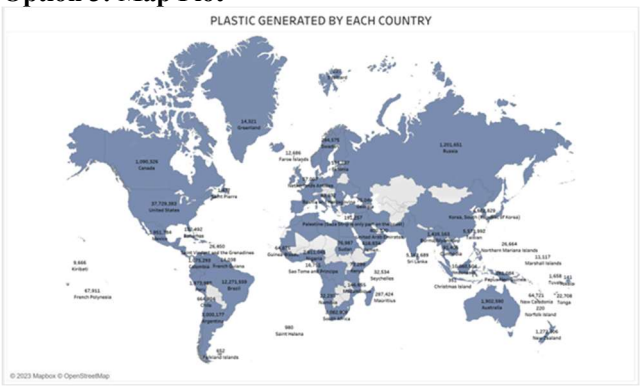

Fig. 7. Amount of Plastic Waste generated by each Country. Based on Plastic Waste data available, the geospatial map summarizes the total amount of Plastic Waste generated by each Country across the map. The amount of Plastic Waste produced and the name of the Country is represented as a label of that Country.

As the third option we have created a Map Plot as shown in Fig. 7. It displays the amount of plastic waste generated by each country. Since the target users already have the knowledge about the geographical locations, they can easily

identify the country on the Map plot. Also, this plot fits in the screen perfectly and does not require the users to scroll to find a country they are looking for.

User Task 2

For the user task two of providing the amount of plastic waste that is mismanaged by each country across the world in 2010 and 2025 (Predicted data in dataset) has an {action, target} pair as {Summarize, Trends}. The users will be able to summarize the trends of mismanaged plastic waste by each country in the years 2010 and 2025. For this user task we came up with idioms that could help us achieve the user task and we finalized the idiom that suits the best by comparing the traits of each of the visualizations.

Option 1: Line Plot

We created a Line Plot as shown in Fig. 8. that shows the trends of variations in plastic waste produced in 2010 vs 2025 between different countries but these line marks do not clearly represent data for this user task we chose and also it doesn't fit in the screen well. It requires the users to zoom in and place the cursor on a specific line to see the quantity of plastic waste produced and the name of that country. So we proceeded to make the second option of Paired Bar Plot for the same user task.

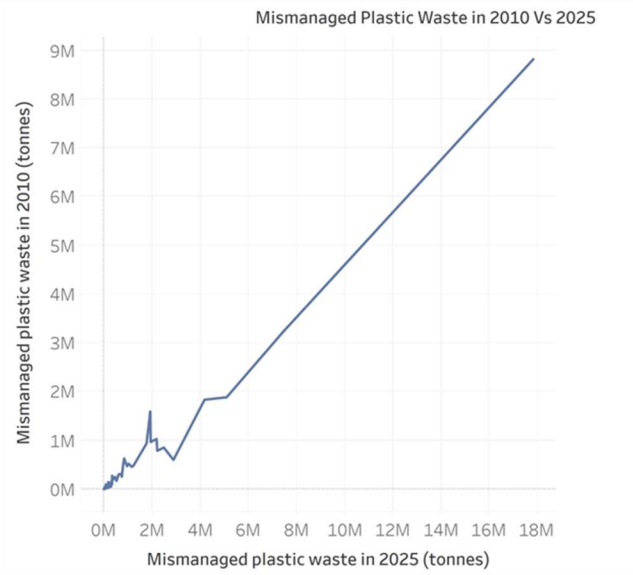

Fig. 8. Mismanaged Plastic Waste in 2010 vs 2025. Based on Plastic Waste data available, the line plot shows Plastic Waste produced by different countries in 2010 and 2025.

Option 2: Paired Bar Plot

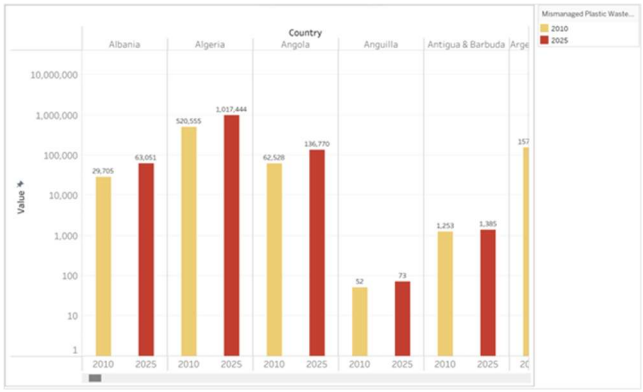

Fig. 9. Mismanaged Plastic Waste in 2010 vs 2025. Based on Plastic Waste data available, the Bar plot shows Plastic Waste produced by different countries in 2010 and 2025.

We created a Paired Bar Plot as shown in Fig. 9. that shows the paired bar plot for the amount of plastic waste that is mismanaged by different countries that was produced in two different years 2010 and 2025 (predicted amount given in dataset) by each country. Using this plot the user can easily see whether the value of plastic waste generated is increasing or decreasing from 2010 to 2025 within the same country and also be able to see the relative increase or decrease with respect to other countries. The bar plot is represented on logarithmic scale along the y-axis for handling display of small values in mismanaged plastic waste, when compared to linear scale that could hardly be able to represent these values due to pixel ratio being too high to fit in display.

User Task 3

For the user task three of providing the Contribution of different plastic waste to total plastic waste generation, has an {action, target} pair of {present, distribution} and the users will be able to see the contribution of plastic waste in different forms to the total plastic waste generated by different countries across the world. Our design choice was a Donut Chart to represent the data for this user task.

Design Choice: Donut Chart

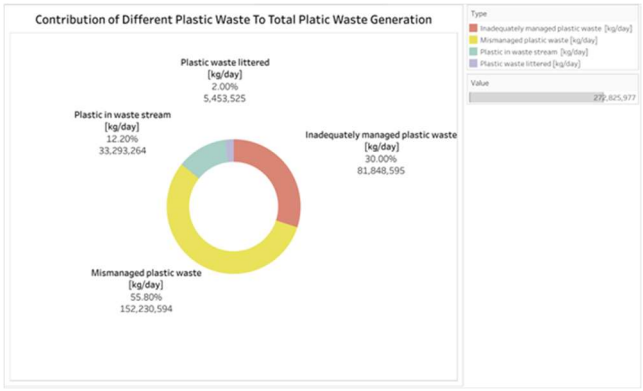

Fig. 10. Contribution of Different Plastic Waste to Total Plastic Waste Generation. Based on Plastic Waste data available, the donut chart shows Plastic Waste in different forms contributing to the Total Plastic Waste generated by aggregating values from all the countries around the world. The area of the donut chart represents the amount of plastic waste contributed by each group.

Here, the color Peach represents the contribution from Inadequately Mismanaged Plastic Waste, Turquoise represents the contribution from Plastic in the waste stream, Gold represents the contribution from Mismanaged Plastic waste and Purple represents the contribution from Plastic waste littered. Mismanaged Plastic waste contributes a total amount of 55.80% of overall Plastic waste generation. The percentage contribution of Plastic Waste littered is not clearly visible on the donut chart, it represents 2% of total area of contribution.

Fig. 10. shows donut charts which gives the percentage contribution of plastic waste in different forms to the total plastic waste generated by all the countries around the world. It clearly shows 4 categories: Inadequately managed plastic waste represented in Peach color, Mismanaged Plastic waste in Gold color, Plastic in waste stream in Turquoise color and Plastic waste littered in Purple color. Using this users can clearly see the contribution of different forms of plastic waste to the total plastic waste generated very easily.

To create this donut chart we have transformed our dataset to make a new subset of our dataset by transposing rows to columns. Tableau does not provide an option to create a donut chart directly but we can create a pie chart and then using dual axis we can create a donut chart. Tableau provides an option to create a pie chart of the different categories that have some common relationship that exists between the columns of the dataset and since we did not have fields that specify the relationship between the columns, we could not generate pie charts in Tableau. To resolve this issue we have transposed our data by changing rows to columns and this established the relation between the different categories of plastic waste generated and we were able to generate the pie chart and then we converted it to donut chart using dual axis.

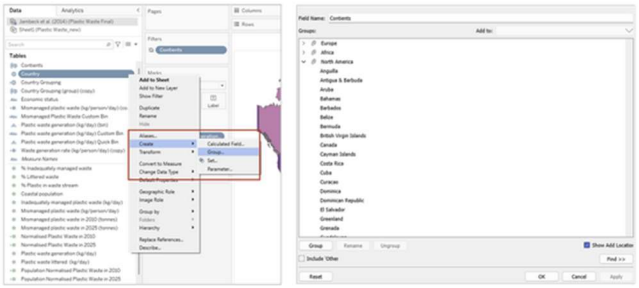

Fig. 11. (a) Creating a group in Tableau. **(b)** Adding Countries to groups in Tableau

To simplify the search and filtering for the users we have added continental hierarchy into the data. Using this filter, users can check the plastic waste summary for a selected continent and its countries. We have achieved this by creating a grouping of countries in Tableau, to do this go to the Country column in the Tables section in tableau and select Create a group by right clicking on the country column as shown in Fig. 11 (a) . Once the pop up opens, select multiple countries using ctrl and left click and then click on Group to create a grouping of countries as shown in the Fig 11 (b). Once the grouping information is created we can drag and drop it into filters so as to create filtering based on continent information.

```
IF  [Plastic waste generation (kg/day)] < 1000 then "<1k"
ELSEIF [Plastic waste generation (kg/day)] <= 50000 then "<=50k"
ELSEIF [Plastic waste generation (kg/day)] <= 500000 then "<=500k"
ELSEIF [Plastic waste generation (kg/day)] <= 1000000 then "<=1000k"
ELSEIF [Plastic waste generation (kg/day)] <= 5000000 then "<=5000k"
ELSEIF [Plastic waste generation (kg/day)] <= 10000000 then "<=10000k"
ELSEIF [Plastic waste generation (kg/day)] <= 20000000 then "<=20000k"
ELSEIF [Plastic waste generation (kg/day)] <= 40000000 then "<=400000k"
END
```

Fig. 12. Calculated field in Tableau

We have also created custom binning of data using the Tableau Calculated fields as shown in Fig. 12. to handle the outliers in the data and represent all the data accurately. Without the custom binning the ranges of bins generated by auto bin in Tableau does not give the user accurate information as the majority of the countries with lower plastic waste generation fall into the same bin.

Fig. 13. Complete Dashboard (a) Original view (b) After filtering the data based on the countries selected.

We have also implemented item filtering which would remove the items that are not of interest to the user, this can help the users to compare specific countries of their choice by selecting and clicking on the countries using the mouse when the control key is pressed on the keyboard that allows multi selection. When the users select multiple countries on the Map plot as shown in Fig. 13.(b) the donut chart now shows only the aggregated contribution of different forms of plastic waste to total plastic waste generated by the countries selected and the bar plot shows only the information for these countries and the rest of the data is eliminated from the view. If the user clicks on the empty space on the Map plot this would deselect the selected countries and the view goes back to the original view as shown in Fig 13.(a). Users can also click a single country of their choice to view the information related to only that specific country. When the user selects multiple countries on the Map plot, the donut chart changes the information from aggregated view to the country specific view that is instead of showing the aggregated data of contribution of different forms of plastic waste to total plastic waste generation around the world it only shows the data specific to the country selected and the bar plot also show the data related to that specific country alone.

4. Results

Color:

We worked with different color themes using different variations of hue, saturation and luminance. We have tried different variations and addressed the issues that we faced with each of them.

Fig. 14. Shows Map Plot using a single hue with different saturations to show the overview of the amount of plastic produced by each country was only effective in showing the highest and lowest plastic waste producing country and it doesn't clearly display the countries that lie in between the different ranges. It gets harder for the target user to get the information about more than 2 different ranges from the visualization. So we tried a different method to improve the information provided to the user by the visualization using multiple hue and variation in saturation.

Fig. 14. Amount of Plastic Waste generated by each Country. Based on Plastic Waste data available, the geospatial map summarizes the total amount of Plastic Waste generated by each Country across the map. Here, the darker the shade of green the higher the amount of plastic waste generated.

Transformation: Semantics:

To make it easier for the user to identify more ranges from the overview map plot we have added bins and categorized the quantitative data into different bins. Here we have used two types of binnings, first is Tableau provided auto-generated bins and custom generated bins.

2.1 Tableau Auto-generated Bins

Fig. 15. shows bins created based on the minimum, maximum, and average values from the data and we only have a few options to control the binning by adjusting the start value, end value, mid value, number of steps. The advantage is that it is quickly available from the dropdown menu. The downside is that if the data is skewed or has outliers the bins created would not help differentiate, as most of the data falls into one or two bins.

Fig. 15. Amount of Plastic Waste generated by each Country. Based on Plastic Waste data available, the geospatial map summarizes the total amount of Plastic Waste generated by each Country across the map and categorizes it into different bins based on the range a country falls into. The color variations define the different categories of bins - the darker the color the higher the Plastic Waste generated and the lighter colors the lesser the waste. Hovering over each of the countries would give the quantity and the name of the country in the form of Tooltip. (These bins are generated by Tableau auto-generate bins)

2.2 Custom Generated Bins

Fig. 16. Amount of Plastic Waste generated by each Country. Based on Plastic Waste data available, the geospatial map summarizes the total amount of Plastic Waste generated by each Country across the map and categorizes it into different bins based on the range a country falls into. The color variations define the different categories of bins - the darker the color the higher the Plastic Waste generated and the lighter colors the lesser the waste. Hovering over each of the countries would give the quantity and the name of the country in the form of Tooltip. (These bins are custom generated accounting for the outliers to better represent the ranges)

As shown in Fig. 16, we can create a custom binning by adding a calculated field in Tableau, here we can specify the individual ranges and their names as per the need. These calculated bins provide more control over the visualization and can convey a lot more information. From Fig. 16 users can now easily identify the highest (400000k colored in dark red), lowest (<1k colored in yellow) and different ranges from the visualization.

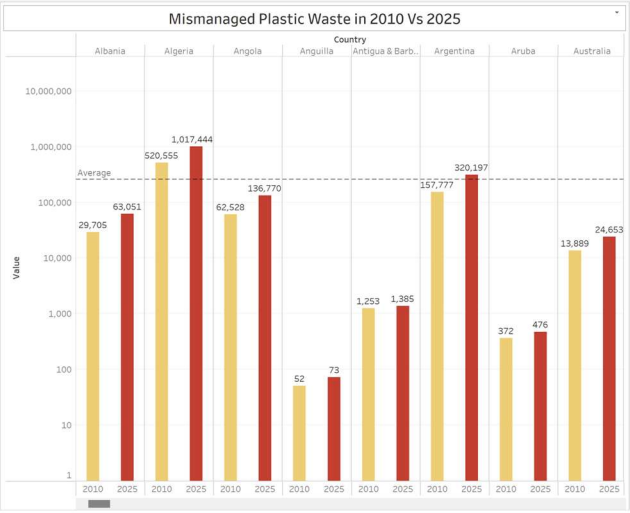

Fig .17. Mismanaged Plastic Waste in 2010 vs 2025. Based on Plastic Waste data available, the bar plot shows Plastic Waste produced by different countries in 2010 and 2025 with length of the bar representing the quantity of plastic waste produced and the colors representing two different years. Here the Yellow colored bar represents the amount of Mismanaged Plastic Waste in 2010 and the Red colored bar represents the amount of Mismanaged Plastic Waste in 2025 (the predicted amount given in the dataset). The scale used is Logarithmic.

Fig. 17. shows the finalized plot for user task 2. The plot used bar charts as marks to display the trends of Plastic waste in 2010 and 2025. This design choice is better for the task listed above as target users can see the value of plastic waste generated in years 2010 and 2025 with help of bar length and conclude if the value of plastic waste generated in 2010 is higher than that is predicted to produce in 2025. The color variations represent the plastic waste produced, with yellow representing the amount produced in the year in 2010 and red representing the amount produced in the year 2025. The change of axis from linear to logarithmic is a better choice as there are outliers in the data, it becomes harder to represent the data values which are very small on the same scale as the large values in the dataset. For the future we want to perform analysis to transform the data so that all the values can be represented in a linear fashion to preserve apparent differences that can be seen with bar length which is lost when the scale is changed to logarithmic.

User Task 3:

Fig. 18. shows the finalized plot for user task 3. The plot uses donut charts as marks to display the percentage contribution of plastic waste in different forms to the total plastic waste generated by all the countries around the world. The color choices were made so that all the categories are clearly visible with their area representing the percentage contribution to the total amount generated in the donut chart. Users can get information such as the total percentage contribution of plastic waste in different forms to the total plastic waste, with information about the percentage contribution of each of its sub-group such as plastic waste littered, inadequately managed plastic waste,mismanaged plastic waste and plastic in waste stream.

Fig. 18. Contribution of Different Forms of Plastic Waste to Total Plastic Waste Generation. Based on Plastic Waste data available, the donut chart shows Plastic Waste in different forms contributing to the Total Plastic Waste generated by aggregating values from all the countries around the world. The area of the donut chart represents the amount of waste contributed by each group. Here, the color Yellow represents the contribution from Mismanaged Plastic waste, Turquoise represents the contribution from Plastic in the waste stream, Purple represents the contribution from Inadequately managed plastic waste and Red represents the contribution from Plastic waste littered. Mismanaged Plastic waste contributes a total amount of 55.80% of overall Plastic waste generation. The percentage contribution of Plastic Waste littered is now clearly visible on the donut chart, it represents 2% of total area of contribution.

Overall Dashboard:

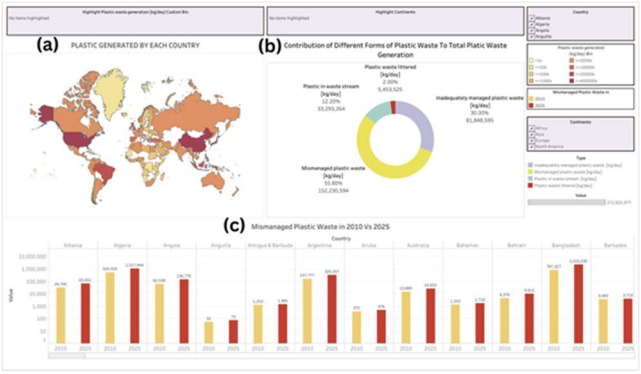

Fig .19. Overview of Plastic Waste generated by each Country. Based on Plastic Waste data available, (a) the geospatial map summarizes the total amount of Plastic Waste generated by each Country across the map and categorizes it into different bins based on the range a country falls into. The color variations define the different categories of bins - the darker the color the higher the Plastic Waste generated and the lighter colors the lesser the waste. Hovering over each of the countries would give the quantity and the name of the country in the form of Tool tip. Beside the geospatial map, (b) the donut chart provides the details of Contribution of Different Forms of Plastic Waste to Total Plastic Waste Generation. Based on Plastic Waste data available, the donut chart shows Plastic Waste in different forms contributing to the Total Plastic Waste generated by aggregating values from all the countries around the world. The area of the donut chart represents the amount of waste contributed by each group. Here, the color Yellow represents the contribution from Mismanaged

Plastic waste, Turquoise represents the contribution from Plastic in the waste stream, Purple represents the contribution from Inadequately managed plastic waste and Red represents the contribution from Plastic waste littered. Mismanaged Plastic waste contributes a total amount of 55.80% of overall Plastic waste generation. The percentage contribution of Plastic Waste littered is now clearly visible on the donut chart, it represents 2% of total area of contribution.. Below the geospatial map, (c) the bar plots provide details of Plastic Waste produced by different countries in 2010 and 2025 with length of the bar representing the quantity of plastic waste produced and the colors representing two years, 2010 and 2025. Further filtering can be applied to narrow the comparisons of Plastic Waste generated by selecting the countries from the Country filter menu or by highlighting the countries which fall into a certain range by selecting the required range in the Highlight Bin filter on the top.

Fig .20. Dashboard with linked filters and the legends to their respective plots, the last image shows the filtered data corresponding to only 3 countries that are selected by the user on the Map Plot and the filter is applied to donut plot and bar plot as well.

Future Work:

We faced a limitation with Tableau Public that is when we have more than two axes to combine and make it into a single visualization, this is not allowed by Tableau and it can only support combining dual axes. When there are more than two, it only combines two and the third axis is displayed by splitting the screen into top and bottom and displaying each respectively in them. Tableau also had a limitation that when the user highlights a country by hovering over the country of their interest in user task 1 should also highlight the country in user task 2, this is supported to some extent but when the country that is selected in user task 1 is not in the visible screen of Tableau it does not scroll to show that specific country. So in the future we want to handle this by integrating Tableau with Python using TabPy and write code to handle this.

In our future work we are intended to expand the dataset by including the data from more sources and years which could provide further insights about the plastic generation and their management all over the world. Also we are planning to try advanced visualization techniques (like virtual reality, machine learning algorithms) which helps the user to dive deeper into the data. Furthermore, we hope to work with other social organizations and governments to identify and solve crucial problems related to plastic waste generation.

Validation:

In the future we want to validate our work for its effectiveness by conducting a survey to know the effectiveness of each of our visualization idioms that we used to help users to accomplish a specific user task. To conduct the survey first we have generated the dashboard using Tableau and posted it on the public server and created a form with questions that needs to be answered based on the dashboard that we have created. We tried to embed the dashboard into the form and also included a link to access the dashboard on Tableau Public server. The participants of this survey would use the link: https://form.jotform.com/231195868276065 to access the survey and answer the questions provided in the survey. Based on the feedback from the participants we would analyze the effectiveness of visualizations. Our survey contains questions on user tasks such as “find the country with the highest amount of plastic waste generation”, “Is the general trend of mismanaged plastic waste increasing or decreasing from 2010 to 2025?”, “What is the percentage contribution of plastic waste generation to the total waste generation ” that would help us understand the effectiveness of the visualization based on the percentage of correct answers provided by the participants. If the majority of the participants are not able to get the correct answers to the questions then the idioms are not very effective for the specified user tasks and needs to be improved to make it effective for those specific user tasks. Once the survey is completed by 50 - 100 participants, we would perform 2 tests that are Accuracy test and Preference test. The Accuracy Test is based on the percentage of participants that were able to give the correct answers based on the visualization that they were provided with , if the accuracy

is below 80% we would estimate that the idioms used are ineffective. We have considered 80% as the baseline for effectiveness as 80% is considered as good in an academic setting. In the Preference Test, the participants provide a rating on a 5-Point Likert scale of range 1 to 5 (where 1 means strongly disagree and 5 means strongly agree) on how easy was it to perform a specific user task using the idiom that we used for the visualization and based on this score we can evaluate the efficiency of our visualization idioms individually.

Accuracy Test:

Once the survey is completed we would create a table that capture the number of correct answers of each of the 4 question

Table 1. The example distribution of correct and wrong answers provided by the participants.

Question	Correct	Wrong
Q1. Which country produces the highest amount of Plastic Waste?	89	11
Q2. Using Bar Plot (Mismanaged Plastic Waste in 2010 vs 2025) is the general trend of mismanaged plastic waste increasing or decreasing from 2010 to 2025?	90	10
Q3.Using the Donut Plot (Contribution of Plastic Waste to Total Waste Generation) enter the percentage contribution of Plastic waste generation to Total waste generation in the box provided	85	15
Q4. What do you think the dashboard is talking about?	92	8
Total	356	44

Then we would calculate the accuracy using the formula given:

Accuracy = (Total Correct * 100) / (Total Correct + Total Wrong)

This gives the accuracy percentage and we will make the decision as follows, if the value of accuracy is less than 80% then it would help us understand that the idioms used are not effective for the user tasks. From the above provided Table 1. the accuracy would be (356) * (100) / (356+44) = 89% which is above 80% and we would consider our visualization to be effective.

Preference Test:

Table 2. The average rating and number of yes/no for the task performed using each of the visualizations.

Idiom	Able to perform user task		Rating
	Yes	No	
Map Plot			
Bar Plot			
Donut Plot			

If the individual rating of any of the idioms is less than 3.5, we would consider it as ineffective for the specific user task. We chose 3.5 as it would be considered as an average case in a general setting. Also, we would calculate the individual percentage of "yes" for the user task to know how easy and effective to use the visualization to accomplish the user task.

Conclusion:

Our group's objective was to come together and show the amount of plastic waste that was mismanaged by using visualizations to highlight this information to our readers. When working on our project and in creating our user tasks, we have given ourselves a better understanding as to not only the amount of plastic waste but also the reasons behind the large amount of plastic waste. We want our target audience to really understand the severity of this on the Environment which would in turn affect our way of living. So we want this information and visualizations to be spread wide across to make more and more people aware to go and

make a small change by decreasing the usage of plastic that would make a drastic change leading towards a better life.

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REFERENCES

[1] J. R. Jambeck, R. Geyer, C. Wilcox, T. R. Siegler, M. Perryman, A. Andrady, R. Narayan, and K. L. Law, "Plastic waste inputs from land into the Ocean," Science, vol. 347, no. 6223, pp. 768–771, 2015.

[2] "Tableau Public," Public.tableau.com. [Online]. Available: https://public.tableau.com/app/discover. [Accessed: 23-Apr-2023]

[3] S. L. Wong, B. B. Nyakuma, K. Y. Wong, C. T. Lee, T. H. Lee, and C. H. Lee, "Microplastics and nanoplastics in global food webs: A bibliometric analysis (2009--2019)," Marine pollution bulletin, vol. 158, p. 111432, 2020.

[4] G.-C. Grün, "The plastic problem in figures – DW – 12/30/2016," dw.com, 06-Nov-2017. [Online]. Available: https://www.dw.com/en/six-data-visualizations-that-explain-the-plastic-problem/a-36861883. [Accessed: 07-May-2023].

[5] E. G. Shershneva, "Plastic waste: global impact and ways to reduce environmental harm," in IOP Conference Series: Materials Science and Engineering, vol. 1079, no. 6, pp. 062047, 2021.

[6] L. Lebreton and A. Andrady, "Future scenarios of Global Plastic Waste Generation and disposal," Palgrave Communications, vol. 5, no. 1, 2019.

[7] J. Royle, B. Jack, H. Parris, T. Elliott, A. C. Castillo, S. Kalawana, H. Nashfa, and L. C. Woodall, "Plastic drawdown: A rapid assessment tool for developing national responses to plastic pollution when data availability is limited, as demonstrated in the Maldives," Global Environmental Change, vol. 72, p. 102-442, 2022.

[8] H. Ritchie and M. Roser, "Plastic Pollution", *Our World in Data*, 2018.[Online].Available: https://ourworldindata.org/plastic-pollution?utm_source=newsletter. [Accessed: 23-Apr-2023].

[9] Kitware, Inc. The Visualization Toolkit User's Guide, January 2003.

[10] W. E. Lorensen and H. E. Cline. Marching cubes: A high resolution 3D surface construction algorithm. SIGGRAPH Computer Graphics, 21(4):163–169, Aug. 1987. doi: 10.1145/37402.37422

[11] S. McKenna, M. Meyer, and A. Lex, "Visualization design worksheets," *Visualization Design Worksheets | Supplemental Materials*, 2017. [Online]. Available: https://design-worksheets.github.io/. [Accessed: 11-Mar-2023]

[12] A. Woodruff and D. Heyman, "Colorbrewer 2.0," *ColorBrewer*. [Online]. Available: https://colorbrewer2.org/#. [Accessed: 13-Mar-2023].