Problem Chosen	2020 MCM/ICM Summary Sheet	Team Control Number
E		**2020276**

Global and Regional Plastic Waste Measurement and Improvement

Summary

Plastic waste has become an important environment problem in the world nowadays. The imbalance between plastic generation and recycling causes that numerous plastic waste entered the environment. These plastic waste not only affects the survival of animals, but also affects human beings in various aspects. Therefore, it is urgent to control plastic pollution.

First, in order to measure the mitigated level of global plastic waste without further environmental damage, we estabilsh **Global Plastic Waste Valuation Model**. We choose possible impact factors and use **Grey Relational Analysis** to filter these impact factors. The **generation and recycling rate of plastic waste** is filtered and we adopt **Multiple Nonlinear Regression Analysis** to bulid relationship between mitigated level of global plastic waste and thest filtered impact factors. With the relationship, the maximun level is calculated to be **672 million Mt**.

Next, considering the regional disparity, we propose **Regional Plastic Waste Valuation Model**. Adjustment coefficient of policy and alternatives to plastics is proposed to adjust generation and recycling rate of regional plastic waste. Policy has impacts on domestic plastic watse generation, imported-exported plastic watse, and recycling rate through policy adjustment coefficients. Meantime, adjustment coefficient of alternatives to plastics influences the recycling rate. We take **China's Trade Ban** and **American Recycling Rate** as examples to verify this model.

Besides, realizing the severity of current plastic waste, we use **Global Plastic Waste Improvement Analysis** to set targets for generation and recycling rate of plastic waste. We respectively introduce **Polynomial Regression Model** and **Logistic Regression Model** to set generation and recycling rate of plastic waste in the future. With the artificially set indicators, we can achieve the maximum level of mitigated global plastic waste in 2050.

Last, because of the regional development differences, we propose **Regional Responsibility Measurement** based on equity. **Entropy Weight Method** is adopted in this model to distribute responsibilities according to GDP, plastic waste generation, and mismanaged plastic waste.

To conclude, global and regional plastic waste models are proposed to measure and improve plastic waste and protect environment. **Sensitivity analysis** has shown that these models are stable.

Keywords: Plastic Waste; Regression Model; Entropy Weight Method

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Contents

1 Introduction

1.1 Background

Plastics have become an indispensable part of various fields today, such as aerospace, transportation and agriculture. Because of plastics are cheap, convenient and lightweight, their **generation** has increased exponentially. However, nearly 79% of plastics in the world today have descend to **plastic waste** [1] for plastics are not easy to degrade. Plastic waste would exist in the environment for a long time, easily causing soil pollution, groundwater pollution, etc. Besides, most plastics would end up in the ocean along with rivers [2] and be broken down into microplastics by waves and sunlight. When animals eat microplastics in the environment by mistake, it will eventually affect the health of people at the top of the food chain with biomagnification [3]. This imbalance between generation and discard intensifies environmental pollution. Therefore, it has become an important issue to find appropriate ways to reduce the plastic generation or to find recyclable alternatives to plastics.

1.2 Literature Review

Without doubt, most of plastic waste ends up in landfills, but there is also 3% that enters the ocean [4]. Plastic materials are usually less dense than water, which makes them float at the ocean surface. However, the estimate of the amount of plastic floating is far less then 8 million tonnes in the order of only 31.25% [5]. Whatsmore, plastic debris affect wildlife in three key pathways: entanglement, ingestion, and interaction [6]. Animals will trip over plastic waste, be trapped by them, or be choked when eating them.

1.3 Our Work

For the sake of unterstanding the plastic waste in environment, we analyzed the impact factors and filtered the most important indicators. Then we establised the **Plastic Waste Model**, which reflects the relationship between mitigated plastic pollution and these indicators. Besides, we calculated the improvement of plastic waste to prevent the further environment damage. At last, the responsibility of each region is distributed through the proposed **Regional Responsibility Measurement**.

- To measure the severity of global plastic pollution and to prevent further environmental damage, we assessed the factors that contribute to global plastic waste. On this basis, we established a **Global Plastic Waste Valuation Model (GPWVM)** and calculated the maximum mitigated plastic waste without causing more environmental pollution.
- Considering the regional differences, we proposed **Adjustment Coefficients** of policy and alternatives to plastics. And based on the Adjustment Coefficients, we modified the GPWVM to **Regional Plastic Waste Valuation Model (RPWVM)**, which reflects each regions' plastic waste.

- With the GPWVM and RPWVM, we have verified the severity of plastic waste problem. Thus, we set a target for the minimal achievable level of **Global Plastic Waste Improvement**. Whatsmore, we used **Polynomial Regression Model** and **Logistic Regression Model** respectively to adjust the generation and recycling rate of plastic waste without further plastic pollution.
- Because of the large difference between regions, we further advised that different regions should be responsible for different regional plastic waste to achieve the global target together. We proposed **Regional Responsibility Measurement** to distribute responsibilities of different regions.

The process of our models is shown in Figure 1.

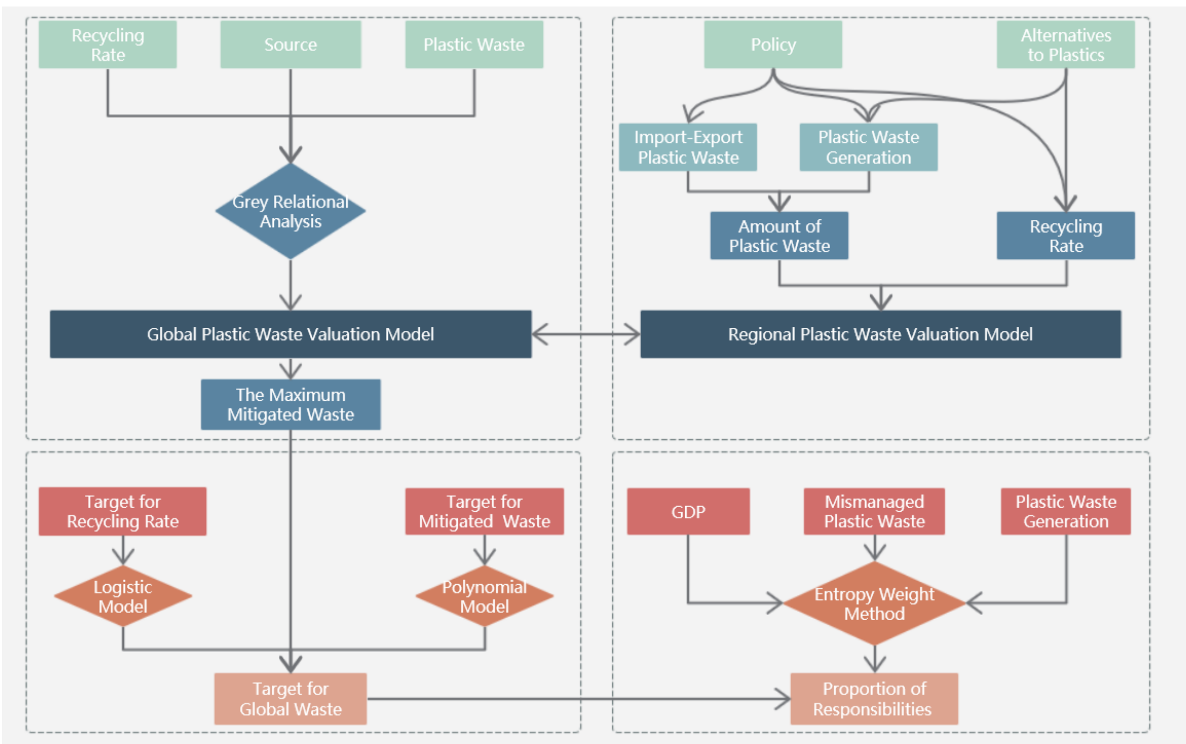

Figure 1: The process of our models

2 Preparation of the Model

2.1 Assumptions and Justifications

In order to simplify the problem, we make assumptions as follows and each of these assumptions is reasonably justified.

1. The environment does not have the ability to degrade plastics. Because the degradation time of plastics in the environment is much longer than that we consider in our model. So

in our model we do not take the ability of the environment itself to degrade plastics into account.

2. With the development of science and technology, the recycling rate of plastic waste can reach 100%. We can completely mitigate the plastic waste without futher environment damage.

3. The condition of plastic generation and recycling rate is stable in a short-term. To simplify our model, we eliminate the influence of accidents like terrorist attack, or an explosion accident caused by a workman's mistake.

2.2 Notation

In this paper we use the nomenclature in Table 1 to descibe our model. Other symbols that are used only once will be described later.

Table 1: Nomenclature

Symbol	Definition
G	Primary plastic waste generation (million Mt per year)
X_i	the i-th impact factor of primary plastic waste
A_j	the j-th impact factor of regional responsibility for plastic waste
Rr	Recycling rate of plastic waste (%)
Ri	Incineration rate of plastic waste (%)
Cp	Policy adjustment coefficient
Ca	Adjustment coefficient of alternatives to plastics
I	Import amount of plastic waste (million Mt per year)
E	Export amount of platsic waste (million Mt per year)

3 Global Plastic Waste Valuation Model

In order to estimate maximum mitigation in plastic waste, we develop a model to associate the capacity to handle the plastic waste with three factors. To avoid doing more damage to the environment, we should limit the amount of plastic waste generation within that we can handle. To quantify the correlation of factors, we use **Grey Relational Analysis (GRA)** to measure the importance of factors. After that, an equation is set up with the more important factors, and parameters are determined by **Multiple Nonlinear Regression Analysis (MNRA)**.

3.1 Primary Impact Factors

We take three factors into consideration: the source of plastic waste, the current state of the waste problem, and the availability of resources to process the waste.

(1) The source of plastic waste X_1

This factor indicates where plastic pollution comes from, which varies with regions, and there are different difficulties to process the waste comes from different ways. Therefore, we introduce ratio of each source of the waste to reflect the structure of the pollution.

(2) The current state of the waste problem X_2

The present extent of waste problem is related with the production of the plastic. Considering the plastic pollution is not fixed at one place but travel around the world, we use the amount of global primary plastics waste generation G_{glo} to represent the current case.

(3) Availability of resources to process the waste X_3

Resoures to process the waste determine the amount of the plastic waste that we can recycle. Thus, it is proportional to the recycling rate, and we choose the recycling rate of plastic waste Rr_{glo} to reflect this indicator. The more resources we can get to process plastic waste, the higher the recycling rate is.

3.2 Filtered Impact Factors

In this section, with the evalution indicators defined above, we further determine the weights of indicators by **Grey Relational Analysis (GRA)**. GRA is a quantitative description and comparison method for the development and change of a system, which reflects the curve degree of correlation. The basic idea of GRA is to determine whether the connections are closely related by the similarity of the shapes of the reference data column and several comparative data columns.

Based on the attribute type of the original indicators, we use the standard 0-1 transformation and the given optimal interval method to do non-dimensional and normalization with 4 indicators X_0, X_1, X_2, X_3, where $X_i = \{x_{i1}, x_{i2}, ..., x_{in}\}$. X_0 represents the mitigated plastic waste.

$$x'_{ij} = \frac{x'_{ij}}{\sum_{j=1}^{n} x_{ij}} \tag{1}$$

The x'_{ij} here is the standardized value of each evaluation indicator. After standardization, we use x'_{ij} instead of x_{ij} to describe our indicators, and we can get a matrix:

$$(X_0, X_1, X_2, X_3) = \begin{pmatrix} x_{01} & x_{11} & x_{21} & x_{31} \\ x_{02} & x_{12} & x_{22} & x_{32} \\ \vdots & \vdots & \vdots & \vdots \\ x_{0m} & x_{1m} & x_{2m} & x_{3m} \end{pmatrix} \tag{2}$$

Thus, for each row in the matrix, the minimum and the maximum of $|x_{0i} - x_{ji}|\ i = 1, 2, ..., m; j = 1, 2, 3$ can be calculated, from which we can also get $min\{min\{|x_{0i} - x_{ji}| i = 1, 2, ..., m\}\ j = 1, 2, 3\}$ and $max\{max\{|x_{0i} - x_{ji}| i = 1, 2, ..., m\}\ j = 1, 2, 3\}$. With the value of the minimum and maximum, we can find the Correlation Coefficient:

$$\xi_i(k) = \frac{min\{min\{|x_{0i} - x_{ji}|\}\} + \rho \times max\{max\{|x_{0i} - x_{ji}|\}\}}{|x_{0i} - x_{ji}| + \rho \times max\{max\{|x_{0i} - x_{ji}|\}\}} \tag{3}$$

where ρ is the resolution factor, the range of which is usually $(0,1)$. The smaller ρ is, the stronger the capacity to distinguish indicators is. Here we give the value 0.5 to ρ. After finding ρ, we can use it to find the Relevance Coefficient (RC):

$$r_i = \frac{1}{m}\sum_{k=1}^{m}\xi_i(k) \tag{4}$$

The result r_i represents the level of relevance, so we can get the series of the relevance and find which indicator is the closest with the mitigated plastic waste. The result of GRA is shown in Table 2.

Table 2: The result of GRA

	X_1	X_2	X_3
RC	0.68	0.85	0.92

The weight of these indexes are finally decided by GRA. According to the result of GRA, we find that the total plastic waste generation and the recycling rate is significant to the mitigated plastic waste, while the structure of the source of waste is less important.

3.3 Multiple Nonlinear Regression Analysis

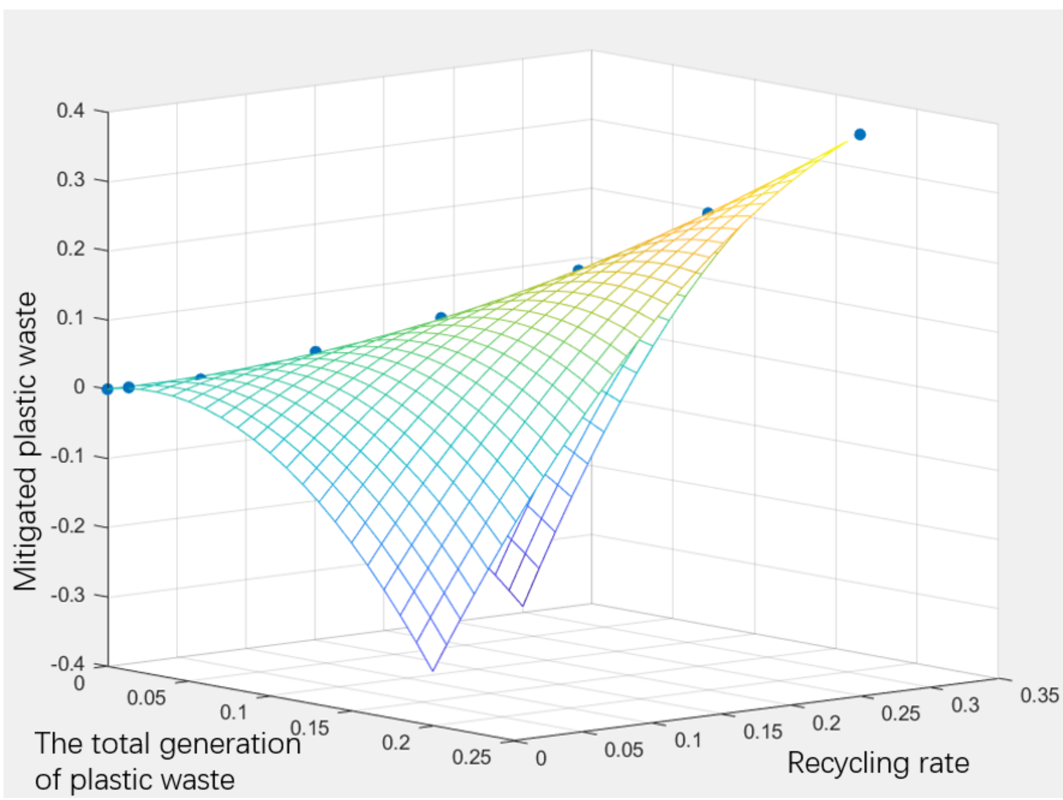

Figure 2: The fitted surface obtained by MNRA

In this section, we use the factors that we picked out before to find out the expression of the mitigated plastic waste by **Multiple Nonlinear Regression Analysis (MNRA)**.

According to analysis, we deduce an equation. The dependent variable is the maximum of reduction of disposable plastic waste y, and we take the total production of plastic waste x_1 and recovery rate of plastic waste x_2 as indenpendent variables.

$$y = -11.1536x_1^2 - 10.4666x_2^2 + 27.9227x_1 \cdot x_2 + 0.6224x_1 + 0.005 \tag{5}$$

Then we look for constraints to determine parameters. When $x_2 = 0$, there is no waste recycled, so there is no doubt that the amount of mitigation y is zero no matter what x_1 is. When $x_2 = 1$, all waste are recycled, then the amount of recycled waste equals the generation.

$$\begin{cases} y = 0, & x_2 = 0 \\ y = x_1, & x_2 = 1 \end{cases} \tag{6}$$

With these constraints, we can find a fitting plane and we can find a point where y reaches the maximum, as shown in Figure 2. Then we got the final result that the maximum mitigated plastic waste is **672 million Mt**.

4 Regional Plastic Waste Valuation Model

Considering the differences between regions, we built Regional Plastic Waste Valuation Model (RPWVM). For the sake of measuring the impact of national policies, the availability of alternatives to plastics on global pollution levels and recycling rate, we proposed policy adjustment coefficient, availability coefficient of alternatives to plastic in RPWVM. Besides, the correlation between regions and global was built. The rationality of the RPWVM is verified by examples.

4.1 Related Variable Coefficients

(1) Policy Adjustment Coefficient

The impact of policies on plastic pollution varies greatly from region to region. We divided the impacted factors into three parts: the plastic waste generation, the plastic waste recycle, and the plastic waste import-export difference.

$$G'_{reg} = Cp_{gen} \cdot G_{reg} + Cp_{ie} \cdot (I - E) \tag{7}$$

$$Rr'_{reg} = Cp_{rec} \cdot Rr_{reg} \tag{8}$$

where:

- G_{reg} is the regional plastic waste genetarion;
- G'_{reg} is the adjustment regional plastic waste genetarion;

- Rr_{reg} is the regional plastic waste recycle;
- Rr'_{reg} is the adjustment regional plastic waste recycle;
- Cp_{gen} is the policy adjustment coefficient of plastic waste generation;
- Cp_{ie} is the policy adjustment coefficient of plastic waste import-export difference;
- Cp_{rec} is the policy adjustment coefficient of plastic waste recycle.

Because policies are difficult to measure directly with data, we use policy adjustment coefficients to indirectly adjust factors according to different policies. In this method, we achieved the assessment of regional single-use or disposable plastic pollution. In Section 4.2, we would take China's trade ban as example to illustrate the indirectly influence of policy.

(2) Adjustment Coefficient of Alternatives to Plastic

Another important way to solve the plastic pollution problem is to find degradable or recyclable alternatives to plastics.

Theorem 1. *The increase rate of alternatives to plastic can represent the adjustment coefficient of alternatives to plastic.*

Proof. The plastic waste can be divided into recyclable and non-recyclable plastic waste. Let P is the amount of plastic waste, P_1 is the amount of recyclable plastic waste, and P_2 is the amount of non-recyclable plastic waste. In a short term, we assume that P does not change. And k percentage non-recyclable plastic waste can be transformed to recyclable.

Then before transformation, we have:

$$P = P_1 + P_2$$

$$Rr = \frac{P_1}{P}$$

After transformation, we have:

$$P = (P_1 + k \cdot P_2) + (1 - k) \cdot P_2$$

$$Rr' = \frac{P_1 + k \cdot P_2}{P}$$

Thus:

$$\delta Rr = \frac{Rr'}{Rr}$$

$$Rr' = \delta Rr \cdot Rr$$

From what has been discussed above, we draw a conclusion that:

$$Ca = \delta Rr$$

Proof done. □

According to **Theorem 1**, we define that:

$$Rr'_{reg} = Ca \cdot Rr_{reg} \tag{9}$$

It can be seen that alternatives to plastic can directly increase the recycling rate of plastic waste by the adjustment coefficient. We take American recycling rate of plastic waste as example in Section 4.3.

4.2 China's Trade Ban

It is common that recycled plastic waste is sold and traded in global commodity market. However, there is an issue that plastic waste from well-management regions to general-even-bad-management regions would aggravate plastic pollution. Brooks et al. [7] analysed that 72.4% of global traded plastic waste had been imported to China and Hong Kong (with most imports to Hong Kong eventually reaching China). However, China introduced a complete ban on the imports of non-industrial plastic waste in the end of 2017.

We use our RPWVM model to estimate the influence of this policy. We believe that the trade ban policy only impact the policy adjustment coefficient of plastic waste import-export difference. Thus we set $Cp_{gen} = Cp_{rec} = 1$ and $Cp_{ie} = 0$. Then, formula (7) (8) can be transformed to formula (10) (11). The domestic and imported plastic waste of China from 2010 to 2016 are as shown in Appendix A.

$$G'_{CHN} = Cp_{gen} \cdot G_{CHN} + Cp_{ie} \cdot (I - E) = G_{CHN} \tag{10}$$

$$Rr'_{CHN} = Cp_{rec} \cdot Rr_{CHN} = Rr_{CHN} \tag{11}$$

We compared the impact of the policy on matigated plastic waste before ($Cp_{ie} = 1$) and after ($Cp_{ie} = 0$) the implementation, and the results are as shown in Figure 3. We suppose that this policy implemented in 2010.

It can be seen that after the China's trade ban, the mitigated plastic watse decreases. It means that China needs to deal with less plastic waste to protect the environment, which is benefit for China to reduce environment pollution.

4.3 American Recycling Rate of Plastic Waste

The United States is the country with the strongest comprehensive national power in the world. However, the recycling rate of plastic waste does not match its overall power.

We compare the United States with Japan in 2010. The per capita plastic waste (kilograms per person per day) of the United States and Japan is 0.34 and 0.17 [4]. And Gross National Product (GDP) per capita (constant 2011 international $) is 49374.18 and 35749.76. It can be seen that the United States has greater per capita plastic waste and GDP per capita than Japan. It partly reflects the fact that the United States has to recycle more waste than Japan and also has a stronger economical power to recycle plastic waste.

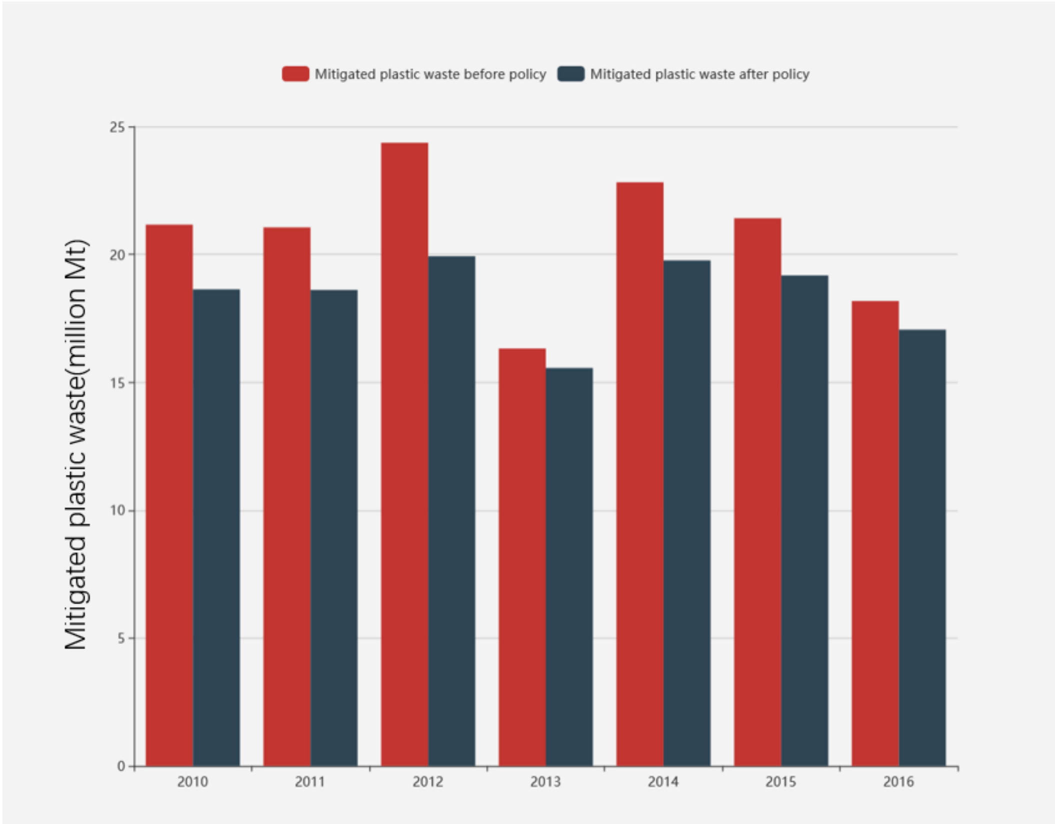

Figure 3: The mitigated plastic waste impacted by China's trade ban

However, the truth is that the recycling rate of the United State (6.61%) is less than Japan (24.80%) in 2010, which is even less than the average recycling rate of global (16.00%). The plastic waste the United States needs to mitigate is 5.4 million Mt. Suppose the United State has the same recycling rate as Japan, then the United States needs to mitigate 15.588 million Mt plastic waste. If the United States chooses to use alternatives to plastics, the adjustment coefficient of alternatives to plastics is 2.752. It is still a long way for the United States to achieve this target.

5 Global Plastic Waste Improvement

After we got the Global Plastic Waste Valuation Model, we realized that if we continue to keep the current development trend, the environmental problems will be very serious. We must take steps to address current environmental problems. We use our model to set a goal by 2050 and analyze the impact of achieving this goal.

5.1 Minimal Achievable Level of Global Plastic Waste

According to the model we established, we obtained a fitted surface of the mitigated plastic waste with the generation of plastic waste and the recycling rate. We have to set a goal for the global total generation of plastic waste, so we must first set goals for human mitigation of plastic waste and recycling rate.

For the recycling rate, the current level is about 0.2, and we hope that the recycling rate for plastics can be increased to 1.0 by 2050. The growth model we set for the recycling rate is based on a **Logistic Regression Model (LRM)**. This is because the current research and development of biodegradable plastics has fallen into a bottleneck, and the growth has been slow in recent years. We believe that if we formulate relevant policies to achieve our goals, the research and development of biodegradable plastics will improve.

For the total amount of mitigated plastic waste, we set a goal to reach the maximum levels of mitigated plastic waste studied in Section 3 by 2050. The specific process we use is a **Polynomial Regression Model (PRM)**, which has a faster growth rate in the early stage and a slower growth rate when it approaches the target.

After we set the recycling rate goal and the goal that humans can mitigate plastic waste, we bring into the model and study the goal of global plastic waste generation at five-year intervals.

As shown in Figure 4, we realized that the full recycling of plastic waste generation in 2050 without further environmental damage.

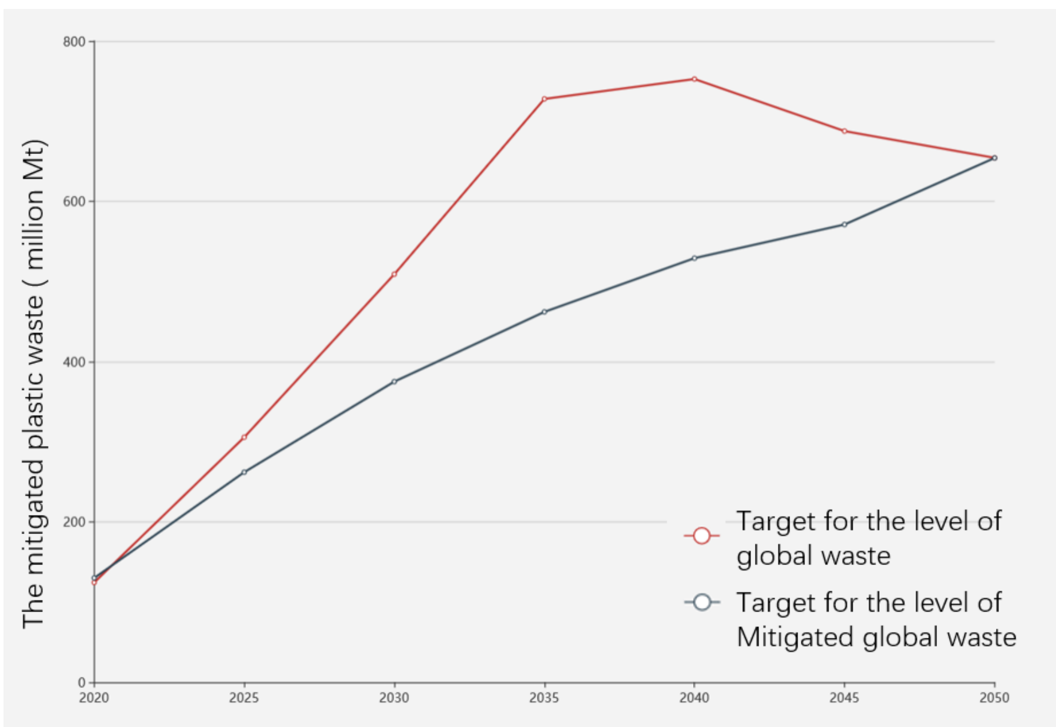

Figure 4: The targets for the minimal achievable level of global waste

5.2 The Impacts of Achieving the Target

(1) Promote the Development of Biodegradable Plastics Industry.

Plastic is such a common material that it is hard for people to stop using it. But to avoid

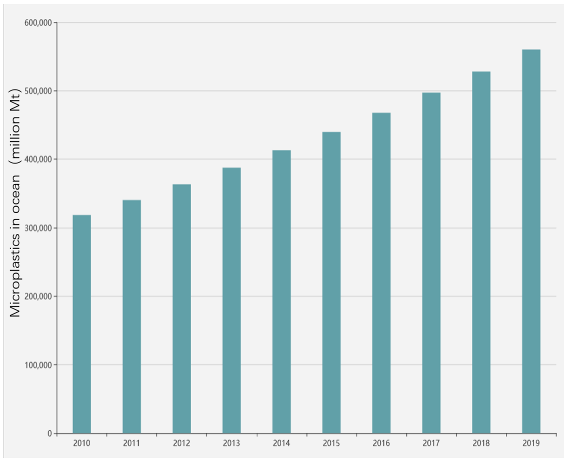

Figure 5: Microplastics in ocean over the year

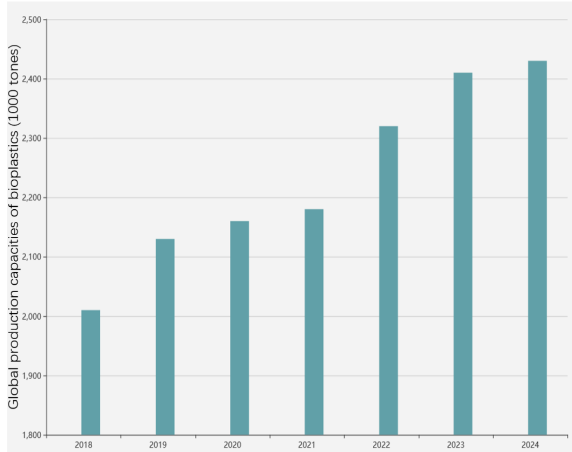

Figure 6: Global production capacities of bioplastics over the year

doing further damage to the environment, we have to replace it with biodegradable plastic, which can be completely degraded and is environmentally friendly. It can be seen in the Figure 6 that the predicted global production capacities of bioplastics is slowly increasing year by year. In the process of achieving this goal, the bioplastics industry will be valued, so its growth rate will increase faster. On one hand, high-tech talents studying bioplastics will be in great demand. On the other hand, workers in the traditional plastics industry will face layoffs.

(2) Change our Lifestyle.

The target can not be achieved with only one man's effort, it needs all people around the world to word hard on it. It is of great importance to raise the awareness of people to protect the environment. People would use paper bags instead of plastic bags, use reusable bottles instead of single-use bottles. And single-use plastic tableware will not appear again.

(3) Better Environment.

After achieving the target, the plastic pollution will be well-controlled. We can see from the Figure 5 that the amount of microplastics in the ocean is increasing year by year. With people protect the envirnment carefully, the amount of microplastics in the ocean will be decreased. Animals in the sea will no longer be troubled with microplastics and live a healthier life.

6 Regional Responsibility Measurement Based on Equity

With all countries working together to achieve the goal of plastics governance, unfair problems will inevitably arise. In some developing countries, the economy is weak. But because of mismanaged problems, more plastic waste is generated. In some developed countries, the economy is leading and because of better management and high investment in research on plastic governance, less plastic waste is generated. At this time, how to divide the responsibilities of each country has become an important issue.

So we decide on several aspects to measure the division of responsibilities, namely the GDP, the amount of mismanaged plastic waste, and the total amount of plastic waste generated by

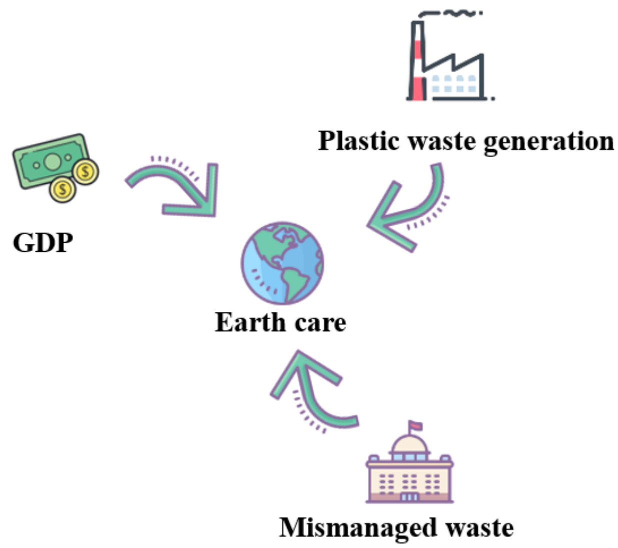

Figure 7: Several impact factors of regional responsibility for plastic waste

the country. We use **Entropy Weight Method (EWM)** to calculate the weight of each aspect. There are 3 indicators of A_1, A_2, and A_3, where $A_i = \{a_{i1}, a_{in}, ..., a_{in}\}$ describe the value of the n country in the i-th aspect. We use the standard 0-1 transform for dimensionless and normalization. Thus we have

$$\begin{cases} y_{ij} = \frac{a_{ij} - min(A_i)}{max(A_i) - min(A_i)} \\ y_{ij} = \frac{max(A_i) - a_{ij}}{max(A_i) - min(A_i)} \end{cases}, j = 1, 2, ..., n \tag{12}$$

where y_{ij} is the standardized value of each evaluation indicator of each size.

After data standardization, we can use y_{ij} to describe each value, and then we have

$$p_j = \frac{y_{ij}}{\sum_{j=1}^{n} y_{ij}} \tag{13}$$

According to the theory of information entropy, the information entropy of each aspect can be calculated, and thus

$$e_j = -k \sum_{i=1}^{n} p_{ij} ln(p_{ij}), j = 1, 2, 3...m, k = \frac{1}{ln(n)} \tag{14}$$

Then, the weight of each aspect can be calculated:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{15}$$

After calculation we get the weights as shown in Table 3.

Table 3: Weights calculated by EWM

	Gross National Production	Mismanaged Waste	Plastic Waste Generation
Weights	0.342	0.307	0.350

Then we multiply the weight by the corresponding value to get the final score. Responsibility is divided according to the score. Higher scores require more responsibility.

$$s_i = \sum_{j=1}^{3} a_{ij} \cdot w_j \tag{16}$$

$$r_i = \frac{s_i}{\sum_{i=1}^{n} s_i} \tag{17}$$

The proportion of responsibilities that each country in the world should assume is shown in Figure 8.

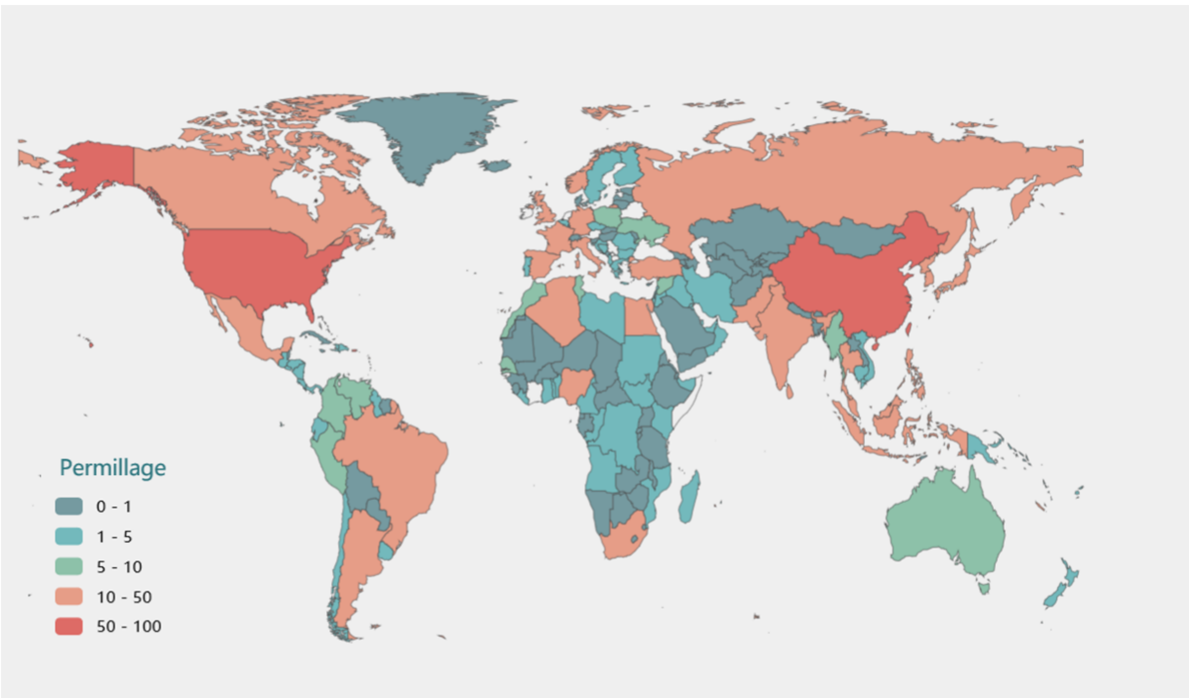

Figure 8: The proportion of responsibilities of each country in the world

It is easy to analyze from the figure 8 that countries with large economies and several permanent members of the United Nations have to bear a lot of responsibilities. We believe that developed countries should take more responsibility to protect the environment of our entire planet in the process of controlling plastic waste.

We also found that several Southeast Asian countries like Thailand, Myanmar, and Indonesia have to take many responsibilities because of having many plastic industries and poor government management. We believe that for this type of country, the United Nations should focus on monitoring and setting certain penalties to force their governments to use strict measures.

7 Sensitivity Analysis

We set ρ to 0.5 when analyzing the influence of various factors on the Grey Relational Analysis. Then we obtained that the recycling rate and the plastic waste generation have a greater impact on the mitigated plastic waste than the source of it. We changed ρ from 0.1 to 0.9 step by 0.1 and plotted the change of the relation coefficient. The results are shown as Figure 9. It can be found that the correlation coefficient of the recycling rate and the plastic waste generation is always higher than the source of plastic waste, indicating that the model is not sensitive to ρ.

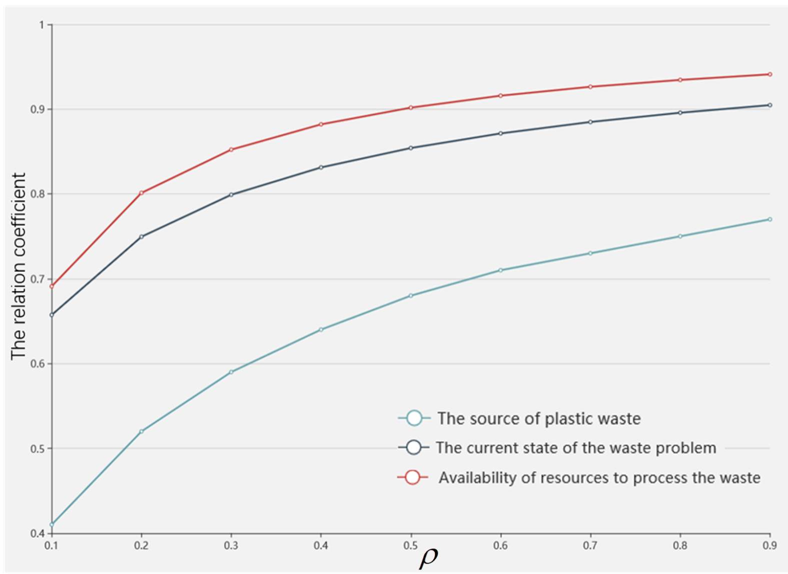

Figure 9: The relation coefficient variation for different ρ

Through previous research, we have established models that estimate the maximum amount of plastic waste that can be mitigated. Then we analyze the sensitivity of this model by changing the recycling rate and the plastic waste generation. The recycling rate and the plastic waste generation are processed by $\pm 5.0\%$ and $\pm 2.5\%$ respectively. We can observe from the Figure 10 and Figure 11 that when recycling rate and the plastic waste generation have small fluctuations, they will not affect mitigated plastic waste but keep the same trend with original results.

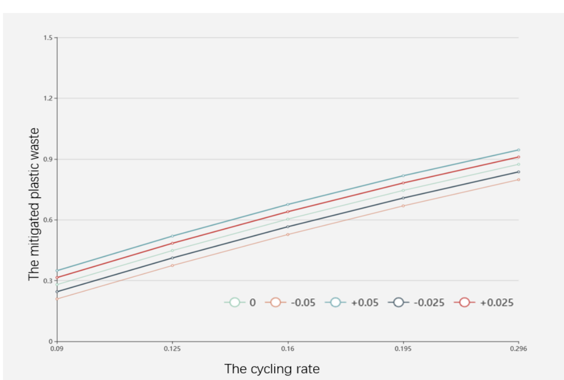

Figure 10: Sensitivity analysis for the recycling rate

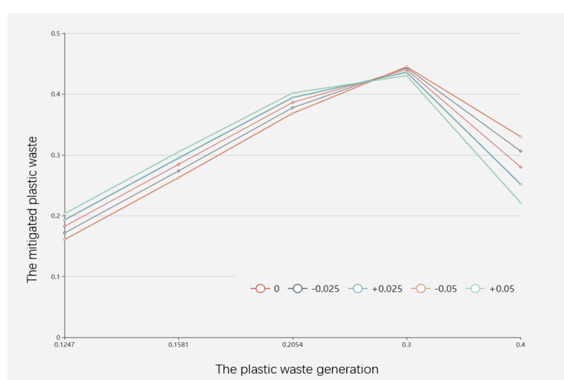

Figure 11: Sensitivity analysis for the plastic waste generation

8 Strengths and Weaknesses

8.1 Strengths

1. We take varieties of factors that affecting the production of plastic waste into account and make a comprehensive analysis, which enables our model to fit a lot of different conditions.

2. Our model applies to both short-term and long-term analysis if we can get corresponding data, which gives our model a wider application.

3. The plane that we predict from plots has a good fitting effect, which means our model is fairly realistic.

4. Each factor's impact is quantitized, so the importance of each indicator can be directly reflected and sorted, through which we can come up with the most efficient way to control the growing amount of single-use or disposable plastic product waste.

5. The sensitivity analysis shows that our model is stable.

8.2 Weaknesses

1. We neglect indicators that have little influence on the amount of plastic waste that can be processed, but virtually, it do make a difference. Our model will be better in conformity with practical situation, if we do not discard unimportant factors.

2. Due to space limits, we only analyze the situation in two particular regions, China and America. However, countries have different circumstances, and two regions can not represent all states.

3. Becaues of the limited data, there is a possibility that factors that we pick can not completely describe the real condition, which may reduce the accuracy of our model.

9 Conclusion

In this paper, we established respectively **Global and Regional Plastic Waste Valuation Model** to understand the severity of global and regional plastic pollution. These models reflect the relationship among plastic waste mitigated, generation, and recycling rate. And we calculated that maximum levels of plastic waste mitigated without further environmental damage is **672 million Mt**. Besides, the **Global and Regional Plastic Waste Improvement Measurement** was proposed to deal with the plastic waste problem. Based on the measurement approach, we set targets for global plastic waste generation and recycling rate to control plastic waste problem. Considering the equity issue, we also set target for each region. Finally, **Sensitivity Analysis** and **Strengths and Weaknesses** has shown that our model is stable. We still need to analyze more regional data to verify our models in the future.

10 Memo

Dear Sir or Madame,

In accordance to your requests, we set up three models to predict the development of single-use or disposable plastic waste and the maximum amount of plastic pollution that people can process, based on which we come up with the final result.

At first, we investigate indicators which have an influence on the development of global plastic waste disposal, and we pick out several main factors to quantize their impacts. Then, we take the effect of local economy and policy into consideration, and predict the future development. We also analyzed the impact of two particular regions. After that, we look into the state of both global and regional plastic waste.

According to our model, we will achieve the target minimum level of global production of plastic waste by 2050.

First, the capacity of processing plastic waste will keep growing for a variety of reasons. With technology being improved, the plastic recycling industry has a continuous trend of development now, and it is even accelerated by the more and more common envirnmentalism.

The plastic waste production will increase and reach the peak at 2040, but start to decrease after that, and it will achieve the target in 2050. This growing pattern is multi-determined.

Nowadays, the plastic production industry is developing rapidly because modern industry has a growing demand of plastic, so it is difficult to stop the trend of growth immediately. However, from our perspective, we can raise people's awareness of protecting the environment to slow down the growing of plastic production. But it is still unrealistic to make the amount of plastic waste meet the amount of that we can process at once.

There are several circumstances that may have an impact on the achievement of the target and timeline.

Technology plays an important role in the reduction of plastic waste. On one hand, if people can come up with a new way to process plastic waste which is quite efficient, or find a good alternative to plastics, it will help reaching our target greatly. On the other hand, if a new way to use plastic is found, it may make plastic popular again and will increase the production and daily use of plastic, which will definitely delay achieving our goal.

Natural disaster also has a great influence. Some serious disasters have a large impact on the world. A hurricane will destroy everything on the land, and some virus will kill thousands of people. All of these disasters will affect our schedule.

War is the most important factor. If the World War III begins in the following 30 years, both the production and recovery of plastic waste will be affected greatly, and it is hard to say whether the amount of plastic waste will increase or decrease.

Moreover, as a student, there are a few ways that we can use to accelerate the achievement of the target. First, we can try to use less plastic products, like plastic cups and plastic straws. Second, we can spread environmentalism and make more people know about the plastic pollution. Futhermore, we can write to government to raise their awareness of problems caused by plastic pollution.

The figure in the end is our suggested timeline.

We hope that our work can provide some useful information for you and we can control the white pollution in the near future.

Yours sincerely,

Team # 2020276

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Appendices

Appendix A Imported and Domestic Plastic Waste of China

The imported and domestic plastic waste (million Mt) of China in 2010-2016

	2010	2011	2012	2013	2014	2015	2016
Imported Plastic Waste	8.01	8.38	8.88	7.88	8.25	7.35	7.35
Domestic Plastic Waste	59.09	59.36	59.67	59.93	60.24	60.55	60.90

Appendix B Grey Relational Analysis

```
a1 = [0    66*0.045    88*0.08  118*0.17   156*0.24   203*0.31   244*0.38   302*0.45];
a2 = [27/50    33/66   44/88   61/118  79/156 102/203  115/244   141/302];
a3 = [50    66    88   118   156   203   244   302];
a4=[0 0 0.02 0.055 0.09 0.125 0.16 0.195];
x0 = a1;
x1 = a2;
x2 = a3;
x3 = a4;
x0 = (x0-x0(1)) ./ sum(x0)
x1 = (x1-x1(1)) ./ sum(x1)
x2 = (x2-x2(1)) ./ sum(x2)
x3 = (x3-x3(1)) ./ sum(x3)
% global minimum and maximum
global_min = min(min(abs([x1; x2; x3] - repmat(x0, [3, 1]))));
global_max = max(max(abs([x1; x2; x3] - repmat(x0, [3, 1]))));
% set rho
rho = 0.5;
% calculate zeta relation coefficients
zeta_1 = (global_min + rho * global_max) ./ (abs(x0 - x1) + rho * global_max);
zeta_2 = (global_min + rho * global_max) ./ (abs(x0 - x2) + rho * global_max);
zeta_3 = (global_min + rho * global_max) ./ (abs(x0 - x3) + rho * global_max);
disp(mean(zeta_1))
disp(mean(zeta_2))
disp(mean(zeta_3))
% visualization
figure;
plot(x0, 'ko-' )
hold on
plot(x1, 'b*-')
hold on
plot(x2, 'g*-')
hold on
plot(x3, 'r*-')
legend('a1', 'a2', 'a3', 'a4')

figure;
plot(zeta_1, 'b*-')
```

```
hold on
plot(zeta_2, 'g*-')
hold on
plot(zeta_3, 'r*-')
title('Relation zeta')
legend('a2', 'a3', 'a4')
```

Appendix C Multipe Nonlinear Regression Analysis

```
y = [0    66*0.045    88*0.08  118*0.17   156*0.24   203*0.31   244*0.38   302*0.45]';
x1 = [50    66    88    118    156    203    244    302]';
x2=[0 0 0.02 0.055 0.09 0.125 0.16 0.195]';
e=sum(y)
y = y ./ sum(y)
a=sum(x1)
x1 = (x1-x1(1)) ./ a
X=[ones(size(y)) x1.^2 x1 x2.*x1 x2.^2 ]
[b,bint,r,rint,stats] = regress(y,X)
Y2=b(2)*x1.^2+b(3)*x1+b(1)+b(4)*x1.*x2+b(5)*x2.^2;
scatter3(x1,x2,y,'filled')
hold on
x1fit = 0:0.01:3;
x2fit = 0:0.01:3;
[X1fit,X2fit] = meshgrid(x1fit,x2fit);
X1a=[590 594 594 599 602 605 609]
X2a=[0.2558 0.252 0.302 0.2029 0.274 0.256 0.2195]
YFa = b(2)*X1a.^2+b(3).*X1a+b(1)+b(4)*X2a.*X1a+b(5)*X2a.^2
%%%%%%sensitivity analysis%%%%%%
%X1b=X1a.*(1-0.025)
%X1c=X1a.*(1+0.025)
%X1d=X1a.*(1-0.05)
%X1e=X1a.*(1+0.05)
%YFa = b(2)*X1a.^2+b(3).*X1a+b(1)+b(4)*X2a.*X1a+b(5)*X2a^2
%YFb = b(2)*X1b.^2+b(3).*X1b+b(1)+b(4)*X2a.*X1b+b(5)*X2a^2
%YFc = b(2)*X1c.^2+b(3).*X1c+b(1)+b(4)*X2a.*X1c+b(5)*X2a^2
%YFd = b(2)*X1d.^2+b(3).*X1d+b(1)+b(4)*X2a.*X1d+b(5)*X2a^2
%YFe = b(2)*X1e.^2+b(3).*X1e+b(1)+b(4)*X2a.*X1e+b(5)*X2a^2
%disp(YF.*e)
YFIT = b(2)*X1fit.^2+b(3)*X1fit+b(1)+b(4)*X1fit.*X2fit+b(5)*X2fit.^2;
mesh(X1fit,X2fit,YFIT)
hold on
%x2=ones(size(x2))
%scatter3(x1,x2,b(2)*x1.^2+b(3)*x1+b(1)+b(4)*x1.*x2+b(5)*x2.^2,'filled')
hold off
```