Simulation of plastic waste model and control plastic waste

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Abstract. Based on this relationship, this paper attempts to ensure the use and development of plastics under the circumstance of minimizing environmental damage. Combined with the actual situation, this paper also puts forward the treatment and treatment of plastic waste in the future and the prevention and control measures. The development of plastic is now a global issue bothering the world for its wide impact on economy, politics and daily life, warning people to take effective measures as soon as possible to control white pollution and protect the ecological environment.

1. Introduction
The production and use of plastic products facilitate people's life and promote the development of science and technology. Among them, single-use and disposable plastic products which dedicates in creating plastic waste, has a significant impact on the development of the world economy as the best economic choice for many enterprises. However, the accumulation of plastic waste has already caused great potential harm to the living environment. To put it simply, there is a violent clash between environment protection and economy development.

Based on this relationship, this paper attempts to ensure the use and development of plastics under the circumstance of minimizing environmental damage. Combined with the actual situation, this paper also puts forward the treatment and treatment of plastic waste in the future and the prevention and control measures.

We are required to develop a model to estimate the maximum level of single use or disposable plastic product waste that can be safely mitigated without further environmental damage. Then, consider the extent to which plastic waste can be reduced to achieve environmental safety. Here, it will be designed into multiple aspects of economic, social and life impacts.

On the basic analysis of the above two questions, we will set a goal for the lowest attainable level of global waste of single use or disposable plastic products and discuss the impact of achieving this level.

Although this is a global problem, its causes and impacts are not equally distributed among countries or regions. In combination with the previous three questions and regional inequality distribution, we will discuss the equity issues arising from the global crisis and expected solutions.

Ultimately, based on the previous modeling results and environmental pollution problems, this paper will provide a two-page memo to describe a realistic global goal.
We aim at offering solutions and suggestions on releasing the world plastic problem. Because of the toughness and complexity of this work, we divide this aim into several goals. We solve this problem by achieving these goals step by step.

**Determine natural and human factors respectively that influence the output of single-use and disposable plastic products.** Establishing a proper evaluation system is critical in this section. And since the causes of output are complex, analyzing these factors is an interdisciplinary problem.

**Develop two models to estimate the level of single-use or disposable plastic waste depending on two systems with different factors.** By doing so, we know better about the balance point in developing the industry of plastic with little harm to ecological system.

**Design a macro intervention plan to improve the plastic situation, targeting at one specific region.** We determine the influential degree of factors in causing plastic waste, thus, we are capable of developing our intervention plan by controlling these influential factors. Thus, we can further discuss the equity issues that arise from the global crisis and put forward solutions in a whole picture.

2. Models

2.1. Basic Model Overview

The goal of solving first problem is to find the maximum value of single-use or disposable plastic product waste that can safely be mitigated without further environmental damage.

In this section, we use Environmental Performance Index (EPI) as the indicator to measure the environmental condition.

We determine important factors involved in the production of single-use or disposable plastic product. The first is the utilization rate of disposable plastic products, and the second is the weighted average coefficient of the impact of plastic products wastes on the environment from different sources. Specifically, plastics can be divided into 7 classes according to their impact on environment. The seventh class represents the eco-friendliest while the first represents the least eco-friendly material. We use the proportion of each class of plastics in the market and its impact on the environment to calculate a weighting coefficient as the weighted average coefficient of the impact of plastic products wastes on the environment from different sources.

Then, we attain the relationship between EPI and these two factors by multivariate non-linear regression and find all the solutions when the value of EPI is at lower limits. After that, we get the relationship between the output of disposable plastic product waste and two factors by multivariate non-linear regression again.

Finally, based on the previous solutions and linear programming to get the maximum levels of disposable plastic product waste. (See Figure 1)

![Flowchart](image)

**Figure 1.** - The flowchart of calculating levels of disposable plastic product waste.

2.2. Basic Model

2.2.1. Assumptions. To simplify our problems, we make the following basic assumptions, each of which will be properly justified.

The data we use has a variation trend to some extent, it will not change suddenly with time.

Environment performance has strong negative relationship with the levels of single-use or disposable plastic product waste.
2.2.2. The Foundation of Model. Environment Performance Index (EPI) is worked out by organizing 24 indicators into ten issue categories and two policy objectives, with weights at each level as a percentage of the total score as below (See Figure 2).

![Figure 2. - The 2018 EPI framework.](image)

When it is lower than 33.3, it means the environmental performance is on the edge of the maximum carrying capacity of the earth environment and threatens human life to a great extent.

Plastics can be divided into 7 classes according to their impact on environment. The seventh class represents the eco-friendliest while the first represents the least eco-friendly material.

| Component | Initial Eigenvalues | Extraction Sums of Squared Loadings |
|-----------|---------------------|-------------------------------------|
|           | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| \( X_1 \) | 3.21  | 64.196       | 64.196       | 3.21  | 64.196       | 64.196       |
| \( X_2 \) | 0.793 | 29.603       | 80.059       | 1.53  | 29.63        | 80.059       |
| \( X_3 \) | 0.66  | 15.974       | 89.029       | 0.66  | 15.97        | 89.029       |
| \( X_4 \) | 0.29  | 0.951        | 100.00       | 0.29  | 0.951        | 100.00       |

Principal Component Analysis Method is used to refine: the utilization rate of disposable plastic products \((X_1)\), the weighted average coefficient of the impact of plastic products wastes on the environment from different sources (the weighted average coefficient calculated according to the own
use proportions of plastic products with a deteriorating impacts scale of 1-7 (X_2), the recycling rate of plastic products (X_3) and the increase rate of plastic production (X_4), these four basic environmental indicators (See Table 1). The Principal Components are not only highly related to the original indicators, but also retain the original useful information of the original indicators, and they are basically not related to each other, thus overcoming the defect of the decline of interpretation ability caused by the correlation between the original indicators.

The characteristic root and variance contribution rate of the correlation coefficient matrix are shown in Table 1 (since the first two principal components have a contribution rate of 93.258% > 85%, the number of principal components refined is m = 2). Finally, the two principal components X_1 (%) and X_2 are used as independent variables and the environmental performance index is used as dependent variable to carry out multiple nonlinear regression modeling to cheat the data from different regions.

2.2.3. **Symbols and Definitions**

| Symbol | Definition |
|--------|------------|
| X_1    | The utilization rate of disposable plastic products. |
| X_2    | The weighted average coefficient of the impact of plastic products wastes on the environment from different sources. |
| Z_1    | Environment Performance Index (EPI). |
| Z_2    | The levels of disposable plastic product waste. |

After we determine these factors, we gather data of these factors from the database of POFTO (Plastic Optical Fiber Trade Organization). Since the second factor (X_2) is defined by us, firstly, we need to preprocess the original data, the proportion of each class of plastics in the market and its impact on the environment, to calculate a weighting coefficient to get X_2 (The resulting data is shown in the appendix).

Through the above methods, collected data are processed appropriately, and the three influencing factors are summed up into two variables. The scatter plot of model 1 is obtained after processing the data. (See Figure 3)

![Figure 3. - The scatter plot of model 1.](image)

Then, we use Matlab2019 for develop the multivariate non-linear regression model and find the solutions. The programs and codes you see will be shown in the appendix.
Figure 4. - Multivariate non-linear regression model 1.

Multivariate non-linear regression model 1:

$$Z_1 = -2.277 \log_2 X_1 - 0.438 X_2 + 100;$$

Coefficient of Determination:

$$R^2 = \frac{SSR}{SST} = \frac{\sum_i (y_i - \bar{y})^2}{\sum_i (\hat{y}_i - \bar{y})^2 + \sum_i (\hat{y}_i - \bar{y})^2};$$

SST.       SSE.       SSR.

$$Z_1: R^2 = 0.534;$$

The value of Multiple R indicates there is a relatively strong association between $X_1$, $X_2$ and $Z_1$.

We knew the lower limits of $Z_1$ is 33.30 based on previous research. In this way, we can get all the solutions of $X_1$ and $X_2$ when $Z_1 = 33.30$, which represents all the possible circumstances that the environmental performance is on the edge of the maximum carrying capacity of the earth environment and threatens human life to a great extent.

Then we use the same method to obtain the relationship between $X_1$, $X_2$ and $Z_2$. The scatter plot is obtained after processing the data. (See Figure 4)
Also, we use Matlab2019 for develop the multivariate non-linear regression model and find the solutions. The programs and codes you see will be shown in the appendix as well.

\[ Z_2 = 66.9564X_1 - 519.6428X_2; \]

Coefficient of Determination:

\[ R^2 = \frac{SSR}{SST}; \]

\[ \sum_i(y_i - \bar{y})^2 = \sum_i(y_i - \bar{y})^2 + \sum_i(\hat{y}_i - \bar{y})^2; \]

\[ \text{SST. SSE. SSR.} \]

\[ Z_1: R^2 = 0.529; \]
And the value of Multiple R indicates there is a relatively strong association between $X_1$, $X_2$, and $Z_2$. With the help of linear programming, the solution of $X_1=94.89$, $X_2=10.87$ is then fed into calculation to obtain the maximum levels of single-use or disposable plastic product waste of single country.

The maximum value of $Z_2$ is 7,049,800 tons. After considering the number of countries worldwide and their levels of development, we estimate the maximum levels of single-use or disposable plastic product waste that can safely be mitigated without further environmental damage is 522,340,000 tons.

According to the report of "world plastics", Freedonia group, a research and consulting agency of world plastics market situation and forecast market, the world's plastic output in 1992 was 103.611 million tons, which is expected to reach 124.05 million tons in 1997, with an average annual growth of about 3.7%; the global plastic consumption in 1992 was 98.094 million tons, while that in 1997 is estimated to reach 118.6 million tons, with an average annual growth of 3.9%.

What the chemical industry, the major consumer industries, the waste industry and the wider society have been missing is a clear prospect, in which a large number of discarded plastics can be recycled and reused. What is also lacking is a comprehensive understanding of where most of the waste will come from and which recycling and recycling technologies have the greatest potential.

According to McKinsey, if the demand for plastics develops according to the current trend, the global plastic waste volume will increase from 260 million tons per year three years ago to 460 million tons per year by 2030, which will raise the already serious environmental problems to a new level.

3. Analysis on Chosen Area

3.1. Choosing an area: Japan and India

Considering that regional specific constraints will obviously expose the direct impact of national policies on disposable plastic waste management, this part attempts to find the quantitative relationship between national macro intervention and disposable plastic waste output. This part also uses the multiple non-linear model constructed by the first question to calculate the required environmental performance index under the environmental safety state, and correspondingly calculates the disposable plastic waste manufacturing volume, and then, in combination with the model in this part, discusses the extent to which countries should regulate and control to achieve the safety, pollution-free and sustainable of plastic products for the environment. Considering the diversity of the actual situation between countries, this part specially selects India and Japan as examples for analysis, so it also has a considerable reference value for other countries.

In this section, we selected Japan and India as the research objects, which have researched the ultimate aerobic biodegradability of plastic materials in the same conditions, and then collected the disposable plastic production volume, environmental pollution degree (in consideration of the Environmental Performance Index in question 1) of these two countries during 2015-2019, as well as the tax rate of enterprises producing disposable plastic products, and the government's scientific and technological investment in solving plastic waste (substitutes, recycling rate, plastic material degradation rate), and the proportion of people who have higher education in this country, who are majoring in environment, materials, chemistry, etc., then study the impact of these factors on the production of disposable products, determine the extent to which plastic waste can be reduced in this country, then analyze another country by the same method, and then compare the two countries, we can see that whether “regional constraints that may make some policies more effective than others”.

3.2. Improved Model

In this part, the business tax rate of one-off plastic production enterprises, the proportion of national scientific and technological innovation investment in plastic pollution to national economic investment and the proportion of students studying environmental science, materials science, chemistry and other related majors to the total number of students in the higher education system are selected.

These three factors represent the macro aspects of national politics, economy, life and education Intervention. In terms of politics and economy, the policy adopted by the state is to levy business tax on
the production of disposable plastic enterprises. [5] At the same time, the state's investment in scientific and technological innovation to a certain extent reflects the country's ability to control plastic pollution, including scientific and technological innovation: research and development of alternative products with less pollution and improvement of recyclability of existing plastic products. [6] In terms of life and education, in the higher education system, the proportion of students majoring in environmental science, materials science, chemistry and other related majors in the total number of students to a certain extent represents the country's relevant talent reserve and social general awareness of plastic pollution control. [7] Therefore, these three indicators are very representative.

Signs and definitions indicated above are still valid. Here are some extra signs and definitions.

Table 3. Extra Symbol Declaration.

| Symbol | Definition |
|--------|------------|
| $Y_1$ (unit: %) | Plastic business tax rate. |
| $Y_2$ (unit: %) | Proportion of science and technology investment. |
| $Y_3$ (unit: %) | Proportion of environmental, material and chemical majors. |
| $p$ (unit: 10,000-ton) | The output of disposable plastic product waste of single country. |
| $P$ (unit: 100,000,000-ton) | The output of disposable plastic product waste of country worldwide. |

Method: In this part, data from Japan and India in recent five years (2015-2019) are selected, and time series theory is used for data processing. After that, the regression model between the three factors and the production of disposable plastic waste was established, and the multiple linear relationship between them was obtained through precise calculation. (The data needed is shown in the appendix.)

Model 3:

$$p = -168.7056x_1 - 101.9928x_2 - 99.7056x_3 + 2662$$

Comparison: According to the chart, compared with Japan, India exerts less pressure on plastic enterprises in terms of taxation, which is due to the different policies adopted by the two countries in terms of taxation. At the beginning of the 21st century, Japan's Taxation Bureau clearly stipulated the quota control of pollution emission tax. Since then, a series of bills have been issued to gradually increase the tax intensity for plastic manufacturing enterprises, so as to curb the further deterioration of plastic pollution. [8] In line with this trend, India's investment in the other two aspects also lags far behind Japan's.

In fact, as a developed country, Japan has not been complacent because of its past achievements. It has always attached great importance to the development of science and technology research and education. It has constantly made bold innovations in the field of science and attached great importance to education. From 2005 to 2016, Japan's research and development on pollution treatment accounted for an average of 3.57% of GDP, ranking first in developed countries. Japan's R & D investment, core technology patents and patent authorization ratio all rank first in the world. However, although India pays more attention to the two aspects, there is still a lot of room for progress. According to Xinhua News Agency New Delhi, the central government of India has introduced new policies to increase investment in scientific research and education support. However, according to the report of ORF, the proportion of R & D expenditure to GDP in India is still one of the lowest levels, so more attention and investment are needed in plastic pollution. [9] These differences are finally reflected in the dependent variable: the manufacturing volume of disposable plastic waste. Under the general trend of simultaneous decrease in the amount of disposable plastic wastes, the gap between the two countries is still about 6 million tons. However, although the two countries have been strengthening regulation and control over the past five years, the amount of disposable plastic waste in Japan has exceeded the maximum standard to the "safe level range", but India is still higher than the maximum standard.

Trend: According to the research, when the environmental performance index is maintained at 40%-60%, the environmental condition of the country is in a safe state. [10] Through the calculation of the above process, we get that about 40% of the countries and regions should maintain the annual production of disposable plastic waste between 5.32-6.54 million tons, and the global annual production of
disposable plastic waste between 270-390 million tons. According to the model calculation in this part, the standards that the state should reach for the four aspects of politics, economy, life and education are obtained (the following table has a detailed description of three index ranges).

|                  | $Z_1$ | $P$ | $Y_1$ | $Y_2$ | $Y_3$ |
|------------------|-------|-----|-------|-------|-------|
| Safe Range       | 60%   | 532 | 5.8-5.9 | 4.1-4.2 | 7.1-7.2 |
|                  | 40%   | 654 | 5.4-5.5 | 3.8-3.9 | 6.8-6.9 |

To include, according to the research and analysis of this model, countries should reasonably increase the attention and management of all aspects of plastic pollution. However, it is worth noting that although in the model, the pollution of disposable plastic products can be reduced by continuously increasing the business tax rate of plastic manufacturing enterprises, when applied to the real world, considering the tax pressure and the survival and development of enterprises, the tax rate should be kept within a reasonable and acceptable growth range and range. [11] Therefore, the state should pay more attention to the investment in science and technology and the cultivation of relevant talents. Generally speaking, these three aspects should coordinate with each other to form a benign interactive and efficient mechanism to fundamentally solve the problem of environmental degradation caused by disposable plastic waste.

4. Strengths and Weaknesses

4.1. Strengths

- One index is used to synthesize the influence of two aspects, which greatly simplifies the complexity and calculation of multiple nonlinear regression.
- The main element analysis method is used to select the representative indicators without losing the key information. It overcomes the defect of the decline of interpretation ability caused by the correlation between indicators.
- Using scatter diagram and function diagram to visualize the relationship between variables and make it clearer.
- Linear programming and decision coefficient are used to increase the accuracy of the model.
- When selecting indicators, considering developed and developing countries, the data is more comprehensive and reliable.
- Make factual analysis based on global real data, and the results are objective and scientific.

4.2. Weaknesses

- Because the disposable plastic problem studied in this paper is affected by many factors at the same time, other factors cannot be completely excluded in the regression analysis, so the fitting degree is relatively low.
- Because of the complexity of statistical data operation, a lot of human and material resources and financial resources will be consumed in the process. There is a certain deviation between the data used in this paper and the real situation of the market.
- In the assessment of the impact of different kinds of disposable plastics on the environment, there are some defects in the quantification of the degree of harm by using Likert scale method.

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