How to Minimize Plastic Waste

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Abstract

This paper is concerned with the problem of the plastic waste. Firstly, we established a multi-objective linear planning model of the impact of plastic based on EP (According to the Eco-Environment Index) and economic losses. Thus, the maximum amount of disposable or disposable plastic product waste that can be safely reduced can be estimated without harming the environment. Secondly, we used APH and normalization methods to build models to analyze the impact of economic development, regional policies, and availability of alternatives on the ecological environment. Thirdly, by taking the plastic industry of Guangdong Province in 2018 as an example, we adopted the differential prediction to predict the lowest level of waste in the 2018 is set as the goal of the maximum level of waste reduction in Guangdong. Finally, we described the per capita GDP and per capita plastic consumption as a main foundation for judging equity distribution about the plastic waste.

Keywords

Plastic waste, Multi-objective linear programming, APH, Difference prediction, Equity problem.

1. Introduction

1.1 Problem Background

The demand and production of plastics are increasing day by day. Their production has surpassed that of most man-made materials. They are synthetic or semi-synthetic organics. They can be manufactured at low cost, are cheap, lightweight, and adaptable in nature. There are countless applications, including food packaging, consumer products, medical equipment and construction. However, its corrosion resistance, short life cycle, low recycling rate, and people's long-term irrational management have led to the deep impact of plastic pollution on the biosphere. Only rarely used plastics can be recycled and reused, instead about 79% are piled up or landfilled. Refractory waste plastic may even eventually enter the ocean through inland waterways, causing the problem of marine plastic pollution becoming increasingly serious.

1.2 Previous Research

There are many models of plastic waste evaluation in the current society, for instance, Yu et al studied 'To Manage the RLs of MSW a multi-objective linear programming was developed MSW Multi linear programming' and established the Multi linear programming model. Then, we searched for a 2008 study by Pati et al. It shows that in the waste paper recycling industry, multi-target research on target planning to design RL networks. In 2016, Dias and Braga Junior surveyed retailers' RL practices and measured the amount of waste generated in each department, using the Wuppertal method in the process

2. Preparation of the Models

2.1 Assumptions

It is assumed that the equivalent factor data corresponding to the region obtained in the study area ecosystem service has certain reliability, otherwise the solution obtained by this model may have certain error with the actual situation.

Suppose that our classification of land already includes all land types, and if the land type is insufficient, the value of the obtained ecological services may be too small.

Because it analyzes a large amount of data when analyzing the real economic cost of small to large projects, it is considered that the data obtained is reliable, otherwise the analysis results will be biased.

2.2 Notations

The primary notations used in this paper are listed in Table 1.

Table 1: Symbols

Symbol	Definition
use_rate	Proportion of different treatment methods for plastic waste
square_land	Land area
square_ocean	Ocean area
α	The amount of incineration in that year
β	The amount of recovery in that year
γ	The amount of discarded in that year
a	The annual global plastic discard rate plastic,1950-2015
b	The annual global plastic incineration rate,1950-2015
c	The annual global plastic recovery rate,1950-2015
d	The global annual increase in plastic,19502015
L	The cost of disposing of plastic waste
EP	Pollution per square kilometer
$h1$	k_Land
$h2$	k_Ocean
$h3$	k_Land_contribution
$h4$	k_Ocean_contribution
m_1	k_past
m_2	k_plastic
$k1$	k_discard
$k2$	k_incineration

$k3$	k_cycle
e	past_plastic
λmax	Maximum eigenvector
w	Corresponding feature vector
CI,RI,CR	Consistency check Standard
$x1$	Existing value of recovery rate
$x2$	Predicted recovery
$x3$	Existing value of incineration ratea
$x4$	Predicted value of incineration rate
$x5$	Current drop rate
$x6$	Predicted drop rate
Z	Plastic reduces level

3. Model Design

3.1 Multi-objective linear programming model

3.1.1 Analysis of the Model

Plastic pollution has aroused widespread concern in the society for a long time. However, despite many related researches on ecosystem value in society, there are still many outstanding problems, for instance, the concept connotation is not uniform and confusing, and the accounting indicators are numerous. The selection of strong subjectivity, etc., results in the interregional and even the same regional accounting results are difficult to compare and analyze, which greatly restricts the practical application of ecosystem value accounting.

Our model draws on the previous research, on the one hand, it can accurately calculate Maximum amount of disposable or disposable plastic can safely reduce product waste without further environmental damage. On the other hand, we take more than three variables into consideration to perfect this model.

3.1.2 Model Establishment

3.1.2.1.Assumptions of the Model In order to obtain the maximum amount of plastic waste that can be reduced without further damage to the environment, we formulate three basic objective functions. Establish a linear program. In the process of using Matlab to solve, successively reduce the range of variables step by step, and finally get the optimal solution. From the reference we simplified the flow chart and got a simple diagram of the plastic life cycle as shown in Figure 1.

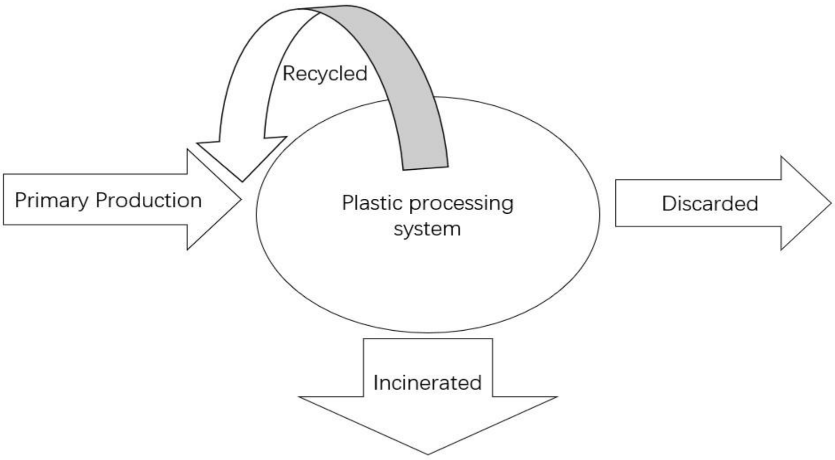
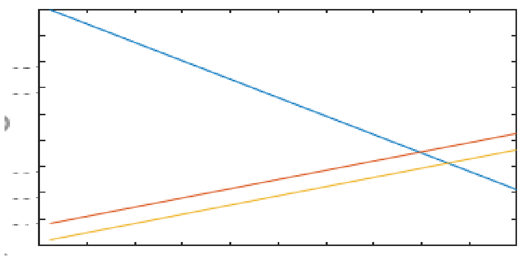


Figure 1: Simple diagram of plastic *life* cycle

3.1.2.2 First goal (Minimal cost loss)

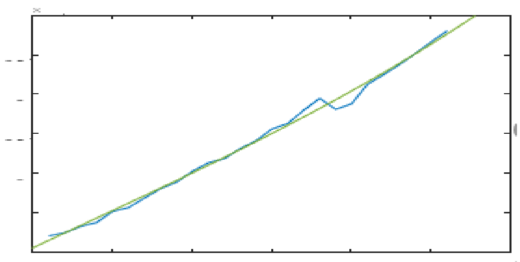
α, β, γ are the three variables of this model, which represent the amount of incineration , recovery and discarded in that year, and the unit is metric ton.

a,b,c,d is based on the data we collected[1], which shows the annual global waste disposal from 1950-2015, a is the proportion of discarded plastic, b is the global annual plastic incineration rate from 1950 to 2015, and c is 1950-2015 The annual global plastic recovery rate, d is the global annual increase in plastic (fiber and resin) output from 1950 to 2015 (in millions of metric tons). The linear incineration rate of plastic incineration, recycling rate and abandonment from 1990 Figure 2 (incineration rate, recovery rate, abandonment rate) and Figure 3 (new net production plastic amount) can be obtained. Table 2 shows the function expressions of the four variables. It can be seen that the residual norm between the fitted curve and the original data is small, so it is feasible to predict future data.



0 5 10 15 20 25 30 35 40 45 50

Figure 2: Annual plastic incineration rate, re-cycling rate and abandonment rate.



0 5 10 15 20 25 30

Figure 3: Annual new net plastic production.

We set a total of two constraints:

First, the sum of the amount of plastic recovered, incinerated, and discarded in the current year does not exceed the sum of the amount of plastic recovered in the previous year and the amount of production in the current year[1]. The previous year's recycling volume is the previous year's plastic production volume multiplied by its recycling rate, and the current year's production volume is the new net production volume for that year.

Second, the actual recovery, incineration, and discarded quantities for that year were less than their predicted recovery, incineration, and discarded quantities.

The cost is limited by α, β, γ, the formula is as follows(1):

$$L = c_1 \times (d(Year-1949) - (\alpha + \beta + \gamma - d(Year-1950,2)) \times use\_rate(Year-1950,4)) + c_2 \times \alpha + c_3 \times \beta \quad (1)$$

c_1 is 772.5 (yuan) profit per metric ton of plastic; c_2 average cost 700 (yuan) per metric ton for incineration; c_3 is 550 (yuan) average recovery cost per metric ton.

When taking the minimum cost of consumption, we can get the value range of α, β, γ.

Table 2: Fitted data

Fitted data	Fit expression	Residual norm
Estimated annual production	$y = 2219x^3 + -20821x^2 + 9.5247e{+}06x + 1.0433e{+}08$	2.95E+07
Expected annual discard rate	$y = -0.014x + 0.914$	5.98E-16
Expected annual incineration rate	$y = 0.007x + 0.073$	2.43E-16
Estimated annual recovery rate	$y = 0.007x + 0.013$	1.75E-16

3.1.2.3 Second goal (Minimal pollution per square kilometer)

The first formula is as follows:

$$EP = \frac{h1(k1a + m1e - k2c)}{square\_land} + \frac{h3(a+b+c) * \frac{8}{270} + h4(a+b+c) * \frac{1}{270}}{square\_ocean} \quad (2)$$

When the minimum EP is taken, the value range of α, β, γ can be further narrowed.

3.1.2.4 The final goal (Maximum and minimum values of plastic increments processed during the year)

After limiting the value range of α, β, γ through the above objectives and constraints, find the difference between the minimum and maximum values to get the maximum amount of waste that can be reduced in the year without further environmental damage, which is 1440 10,000 tons.

3.2 Analytic Hierarchy Process (APH)

In order to minimize plastic waste and achieve ecological and environmental safety, comprehensive policies on plastic products treatment are selected to select the scheme that can achieve the maximum goal. Through the APH model, considering the relevant criteria, the final selection plan is predicted.

3.2.1 Constructing a basic matrix from a model

Based on the original, we make improvements to establish a hierarchical model, as shown in Figure 4:

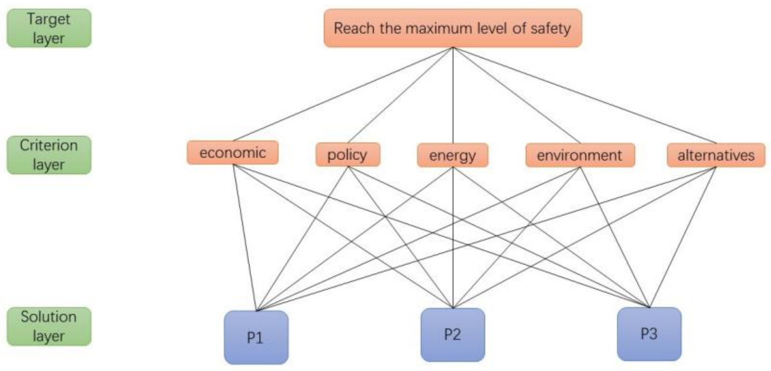


Figure 4: *Hierarchy* diagram

Compare the two factors and construct a comparison matrix according to the importance and scale of each factor. The matrix is as follows and we can get the data by calculation.

$$\begin{bmatrix} 1 & 1 & 2 & \frac{1}{3} & 4 \\ 1 & 1 & 3 & \frac{1}{2} & 4 \\ \frac{1}{2} & \frac{1}{3} & 1 & \frac{1}{4} & 2 \\ 3 & 2 & 4 & 1 & 5 \\ \frac{1}{4} & \frac{1}{4} & \frac{1}{2} & \frac{1}{5} & 1 \end{bmatrix} \tag{3}$$

Three parameters are calculated.

Maximum eigenvector: $\lambda_{max} = 5.082$

Corresponding feature vector: w = [0.195,0.02279,0.097,0.4216,0.0584]

Consistency check: $CI = 0.0205$ $RI = 1.12$ $CR = 0.0183$

Table 4: Stochastic Consistency Index RI

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

By looking up Table 4, we know that in general, when the consistency ratio $CR = \frac{CI}{RI} < 0.1$, the degree of inconsistency of A is considered to be within the allowable range, and there is satisfactory consistency, which passes the consistency test. The normalized eigenvector can be used as the weight vector, otherwise, it is necessary to reconstruct the pair comparison matrix A and adjust a_{ij}.

3.2.2 three kinds of schemes

We mainly choose 3 schemes and list the judgment matrix about 5 criteria.

$$B_1^{(3)} = \begin{bmatrix} 1 & 3 & 4 \\ \frac{1}{3} & 1 & 2 \\ \frac{1}{4} & \frac{1}{2} & 1 \end{bmatrix} B_2^{(3)} = \begin{bmatrix} 1 & \frac{1}{3} & 1 \\ 3 & 1 & 2 \\ 1 & \frac{1}{3} & 1 \end{bmatrix} B_3^{(3)} = \begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{4} \\ 3 & 1 & \frac{1}{2} \\ 4 & 2 & 1 \end{bmatrix}$$

$$B_4^{(3)} = \begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{3} \\ 3 & 1 & 2 \\ 3 & \frac{1}{2} & 1 \end{bmatrix} B_5^{(3)} = \begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{4} \\ 3 & 1 & \frac{1}{2} \\ 4 & 2 & 1 \end{bmatrix}$$

We have calculated five standard feature vectors and corresponding feature vectors for consistency check. These five criteria are economy, policy, energy, environment and alternatives. The table is as follows. Finally calculate the combination weight vector of the solution layer to the target.

Table 5: Hierarchical total ordering

Criterion		economic	policy	energy	environ ment	alternati ves	Total sort weight
Criterion layer weight		0.195	0.2279	0.097	0.4216	0.0584	
Scheme level single order weight	P1	0.625	0.2149	0.112	0.1396	0.122	0.24769487
	P2	0.2385	0.5702	0.3196	0.5278	0.3196	0.43710256
	P3	0.1365	0.2149	0.5584	0.3325	0.5584	0.30255057

Note:

P1: the development of the economy is dominant, and environmental protection is secondary;

P2: introduce policies to reduce the source and use of plastics;

P3: Add plastic alternatives

The basis listed is as shown in the table 5. There are tables to know how to calculate the unknowns we need. As a result, the five matrices pass the consistency check

3.3 Difference prediction

3.3.1 A target for the minimal achievable level of global waste of plastic

2018 is the adjustment period for China's industrial transformation, and issued a number of policies to reduce emissions. Under the policy again, Guangdong 's plastic output is estimated from the per capita GDP and per capita plastic consumption analysis to reach the minimum waste level. Impact of the national economy.

Our work

step **1** We use the representative data from 2018 to build a differential prediction model, predict the minimum output, and calculate the waste level, per capita GDP reduction and per capita plastic consumption.

step 2 We then combined ecological and economic analysis to reduce the impact of waste levels on life

According to the production data of Guangdong from February to June in 2018, the data can be obtained as shown in Table 6.

Table 6: Guangdong's plastic production from February to June in 2018

2018	February	March	April	May	June
Production (in MT)	101.52	103.76	98.22	96.38	95.46

According to the characteristics of the data, if it is considered that the output in the second half of the year is linear with the output from February to June, we use regression analysis to establish a first-order difference equation(4).

$$y = at + b^{1} \quad (4)$$

[1] y is the output in the second month (in 10000 tons) and t stands for month ($7 \le t \le 12$)

Using Matlab's solution, we can get a = -2.096 and b = 105.21, so the first-order difference equation is solved as

$$y = -2.096t + 105.21 \quad (5)$$

According to the equation, July production is 90.538 MT, August production is 88.422 MT. Due to too little data, it is found that the fitting effect of regression analysis is not necessarily good.

So, in order to better fit the data, establish a second order difference equation.

$$y_t = a_1 y_t - 1 + a_2 y_t - 2 + a_3 \quad (6)$$

We choose a_1, a_2, a_3 to minimize

$$\sum[y_t - (a_1 y_t - 1 + a_2 y_t - 2 + a_3)]^2 \quad (7)$$

for the observed data y_t(t=1,2,3,4,5)

According to the equation, a_1 is 0.352, a_2 is 0.0492, a_3 is 56.7059. So, the second-order difference equation is solved as,

$$y_t = 0.352 y_{t-1} + 0.0492 y_{t-2} + 56.7059 \quad (8)$$

According to the equation, July production is 59.0629 (MT), August production is 59.4639 (MT).

2018 output = (February + March + April + May) / 4 * 12 = 19.9964 (MT)

2018 forecast output = (February + ... + August) /6*12=1161.828 (MT)

2018 maximum reduction level = 1199.64-1161.828 = 37.812 (MT)

3.3.2 The impacts of achieving the final target

Impact on the economy Based on 2016-2018 data: Guangdong's average output is 1000MT, accounting for 14.2% of the country.

The average income was 456.3 billion yuan, accounting for 21.5% of the country.

The average profit was 24.2 billion yuan, accounting for 19.61% of the country.

So, the output decreased by 37.812 MT, the revenue decreased by 17.35366 billion yuan, and the profit decreased by 9.1505 billion yuan.

In 2018, Guangdong's total population was 113.46 million, GDP per capita fell by 8.064957 yuan, and per capita plastic consumption decreased by 3.3326 kg.

Impact on quality of life

Assuming an average of 70 grams per takeaway package, then per capita takeaway is 47.6 times less, and assuming that the food bag is $\rho = 0.95g/cm^3$, the average quality is 3.325 grams, and 1002.3 fewer food bags per person are used per year.

We estimate that the lowest in the world Reachable level: China 's output is 60.421 million tons, the world 's is 360 million tons, Guangdong 's average output accounts for 2.383% of the world, and the world 's largest can reduce 13.361131 million tons.

4. The equity issues caused by the global crisis

In order to achieve the maximum amount of disposable or disposable plastic product waste that can be safely reduced (without further harming the environment), different plastic distribution schemes can be formulated from different perspectives. For example, based on the national level of plastic production or according to the degree of pollution, according to the amount of plastic consumption (that is, the sum of discarded, incinerated and recycled) to share equity. This allocation can also be made based on the size of the population and GDP. Different distribution principles and methods represent different interests.

4.1 Principles related to the distribution of plastic shares

The solution we propose for the distribution of plastic equity is explained from the following two aspects. Based on the principles of efficiency and fairness respectively, the former focuses on the convergence of per capita plastic consumption under the current status of plastics treatment and long-term global plastic consumption goals. It is based on the principle of shared reality and ignores fairness. The latter is based on cumulative consumption per capita, considers historical responsibility, and emphasizes the principle of equity.

A fair and reasonable distribution scheme will help to reduce the global plastic waste responsibility system and achieve its goals. However, the criterion of per capita plastic consumption is not in line with reality. We have concluded from a literature surveyed by Jambeck that, although there are large differences between countries at different levels of development, the production of plastic waste tends to increase as economic levels improve. Low-income per capita plastic waste is often much less. But when we consider improperly managed plastic waste (considering environmental impacts), this general relationship does not hold. The relationship between the per capita plastic waste generation rate and the per capita gross domestic product (GDP) reflects the fact that global plastics are not treated properly, That is, the incidence of improper waste generation in low-income countries is often very low (because there is little waste per capita), then rises to middle income, and then declines with higher income, an inverse U curve.

As a result, countries in the middle of the global income range tend to have the highest per capita plastic mismanagement. This situation usually occurs in rapidly industrializing countries, but progress has not been made in waste management at the same rate. Therefore, the development of effective waste management infrastructure, especially in middle-income countries, is essential to make progress in preventing plastic pollution. Therefore, when focusing on the cumulative plastic consumption per capita, it is necessary to reduce the amount of plastic discarded as much as possible (which can also increase recycling and incineration or trade in plastic waste), and also respect the development needs of middle-income countries.

Although the principle of fairness is extremely important, under the single principle, extreme distribution results may occur, discouraging the enthusiasm for continued industrial upgrading in some regions. For example, if the principle of fairness is overemphasized, lessdeveloped regions will gain more production rights for plastics, which may to some extent encourage them to produce plastics, which will lead to an increase in global plastics processing capacity.

Therefore, the principle of efficiency has been widely used. This principle pursues the best input-output ratio of distribution, that is, the most effective use of plastic production rights to meet the needs of human social development. Just like the first question, the profit from the production of plastics is limited. Following the principle of efficiency will maximize the total revenue, but it may exacerbate the inequality of plastic production. Therefore, we strive to balance fairness and efficiency, The amount of plastic processed while reducing regional differences.

4.2 Solutions for Plastic Production Rights under the Global Long-Term Environmental Stability Goal

Synthesizing the above models and the criteria of fairness and efficiency of plastic distribution, we propose a multi-index method for allocating equity, that is, mainly selecting two indicators for distribution, namely per capita GDP and per capita plastic consumption. Analyze multiple factors to determine the plastic budget for each country.

Our options for evaluating plastic equity issues include:

The global plastic production budget that meets the long-term global environmental stability goal within a certain period is determined through the EP per unit area of environmental pollution.

Initially allocate the plastic budget of each country based on the relationship between GDP per capita in the base year and plastic waste per capita.

According to the severity of the plastic problem (coastal and terrestrial), the use of plastics in various industries, the ability to handle plastic waste, national policies, and the market share of alternatives, the plastic budgets of countries are adjusted.

Allow the transfer of plastic waste. Therefore, the "national plastic production rights households" in each country are first established to calculate the historical cumulative discards of each country and the profit and loss of their due consumption, and then the world 's long-term global goal of increasing the total amount of plastic waste to be distributed according to the principles of per capita GDP and plastic waste In each country's account, each country establishes a timetable based on the amount of plastic waste under

its account and can conduct international transactions, but by the target year, each country must eliminate the plastic waste deficit.

Taking into account historical responsibilities and respective capabilities, developed countries take the lead in reducing plastic use, and provide funding to middle-income countries, transfer technology, and help build capacity to increase their ability to adapt to and mitigate environmental degradation under the framework of sustainable development

The global long-term goal of reducing plastics has essentially imposed quantitative reductions on plastic production, incineration and recycling obligations for middle-income countries, which is a difficult challenge for middle-income countries. For developed countries, it is objective to promote the development of alternative materials and plastic decomposition technology.

4.3 Analysis of the solution

Although more and more places in the world are investing more and more money in the treatment of plastics, because plastic wastes and their impacts appear to be a gradual process in many ways, I only know that the more serious the problem of environmental pollution caused by plastics has not been scientifically identified. How much plastic pollution is unacceptable.

The determination of global long-term plastic reduction goals requires a comprehensive balance between the severity of the plastic problem, the source of plastics, the ability to handle plastic waste, the national policy and the rise of alternative products, and the need to weigh the growth rate of different plastics output and additives on the economy and society. The risks of losses from natural ecosystems and the economic costs of achieving different reduction goals and the risks of retarding development.

Different countries have different national conditions and different stages of development, corresponding to different value judgments and interest orientations of plastic production, different priority areas of concern, and basic starting points for considering the goal of controlling the growth rate of plastic output globally. Developed countries have completed the modernization process, and the economy and society have tended to develop in a connotative manner. The technology for waste materials such as plastics (referring to incineration and recycling) is mature. For middle-income countries in the industrialization and urbanization stage, with the growth of economic and social development, the corresponding plastic consumption has a continuous growth process. Therefore, middle-income countries pay more attention to the reasonable plastic reduction space necessary to ensure sustainable development. Pay more attention to the fairness of global reduction space allocation. In the future, the more urgent the long-term global emission reduction target, the larger the EP per unit area, and the smaller the global plastic production quota.

Therefore, the selection of global pollution control targets and long-term reduction targets itself involves fairness issues. Of course, it is the common wish of the world to control the delta EP of future plastic pollution changes to the lowest possible level and minimize the negative impacts and possible risks brought by future climate change. However, in the global joint cooperation action, the development needs of middle-income countries and the right to fair development must also be considered. The global goal of controlling the magnitude of changes in plastic pollution requires both further scientific justification and the need to weigh the impacts of environmental (land and ocean) changes, adaptation, mitigation, and development in international negotiations, and ultimately make reasonable choices.

5. Conclusion

For this modeling competition, we have completed the estimation of the maximum level of disposable or disposable plastic product waste based on the current plastic industry and ecological situation, and discussed that plastic waste can be reduced to the impact of policies and the availability of plastic alternatives. To achieve the level of environmental safety, and set a goal for the lowest level of global waste for disposable or disposable plastic products, and analyze the impact on life, environment, and industry to achieve this goal; from modeling As a result, we need to summarize our research results.

First, we established a planning model based on the final flow direction of the waste (recycling, discarding, and incineration). Through constraints on the recovery rate, discarding rate, and incineration rate, finally, a single unit was estimated without causing further damage to the ecological environment. The maximum level of use or disposable plastic product waste is 14.4 million tons.

Secondly, taking Guangdong as an example, we use the APH method to prove that policies with plastic products have a positive impact on reducing the level of plastic waste. At the same time, obtaining constraints in specific regions may make certain policies more effective than others. in conclusion.

Then, based on the first question model and the second question discussion, we set up a differential prediction model to estimate the maximum level of plastic waste that can be reduced, and the impact on GDP per capita and plastic consumption per capita in order to reach this level Of course, environmental protection policies or suggestions for the transformation of the plastics industry can also reduce the level of plastic waste to a large extent, and the lowest achievable level of plastic waste in the world is estimated at 13.361131 million tons.

Finally, our proposed plastic equity distribution solution is based on the principles of fairness and efficiency. First, we mainly rely on the per capita GDP and per capita plastic consumption as a basis for judging equity distribution, and then consider the severity of the plastic problem (coastal and land). Factors such as the use of plastics in various industries in various countries, the ability to handle plastic waste, national policies, and the market share of alternatives, etc., and then adjust the plastic budgets of various countries. At the same time, plastic waste is allowed to move, but countries must eliminate the plastic waste deficit by the target year. Finally, considering historical responsibilities and their respective capabilities, developed countries took the lead in reducing plastic use, and provided funds to middle-income countries to transfer technology and help with capacity building to improve their ability to adapt to and mitigate environmental degradation under the framework of sustainable development.

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