Research on the Current Situation of Global Plastic Waste

Ruicong Zhang[1, a], Min Huang[2,b]

[1]School of Statistics, Shanxi University of Finance and Economics, Taiyuan, Shanxi, China.

[2] Faculty of International Trade, Shanxi University of Finance and Economics, Taiyuan, Shanxi, China.

[a]1025413815@qq.com, [b] hm197346285@163.com

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Abstract: Establish the optimal environmental carrying capacity model based on the variables of the eight types of polymers, the amount of recovery, and the amount of incineration. After determining the weights through the analytic hierarchy process, we use the fuzzy programming principle to use the fuzzy pole of the bounded function under fuzzy constraints. Set the constraint conditions based on the values and solve the optimal value to obtain the world's largest environmental carrying capacity.

1. Introduction

The development of plastic industry has brought great convenience to human life and production, but also caused serious environmental problems, a large amount of plastic waste into the sea, the problem of marine pollution is becoming more serious, it is predicted that if the current trend continues, by 2050, the amount of plastic waste in the sea will exceed the number of fish, which seriously threatens marine ecosystems and biodiversity and affects socio-economic activities and human health. The widespread use of single-use and disposable plastic products is the main cause of a large number of waste plastic waste, 80% of plastic waste is disposable plastic, and according to statistics, only a small number of plastic waste is recycled and reused, and the rest is mostly discarded in the garbage dump or environment. Reducing plastic pollution is a global challenge. In order to solve the problem of plastic waste, we need to take action to reduce the production of single-purpose or disposable plastic products and improve the recovery rate of plastic waste. Because of the different policies and measures of various countries, the effect of implementation is different, so it is not easy to solve the problem of global plastic pollution. A concerted effort by stakeholders to work together to mitigate the benefits of plastic reductions and move towards a society free of plastic pollution.

The article aims to build a model to solve the maximum level of disposable plastic waste without further environmental damage, then selected indicators to take into account the source of plastic waste, the severity of the waste problem and the feasibility of its disposal The objective function is established according to these variables, and the fuzzy maximum of the objective function is obtained under the constraint condition.

2. Optimal Environmental Bearing Capacity Model.

Solve the maximum level of disposable plastic waste without further causing environmental damage. This level is called the maximum environmental carrying level. This article divides the sources of plastics into 8 major types of polymers, namely the above-mentioned HDPE, LDPE, PP, PS, PVC, PET, PUR, PP & A, and the feasibility of treating waste resources into the recovery rate and incineration rate index. The first question analysis is based on the establishment of the objective function based on the above 8 types of polymer production, recovery, and incineration.

The article proposes the following basic assumptions, each of which is correct. Production of single-purpose or disposable plastic products follows a normal distribution. Level of production technology unchanged. Plastic recovery doesn't mutate over time. There will be no war or disaster in the process of achieving the goal.

2.1 Date selection.

According to the data search based on the available resources, the annual output and total annual output, recovery rate and incineration rate of the eight types of polymers from 1991 to 2005 were obtained, as shown in Figure 1.

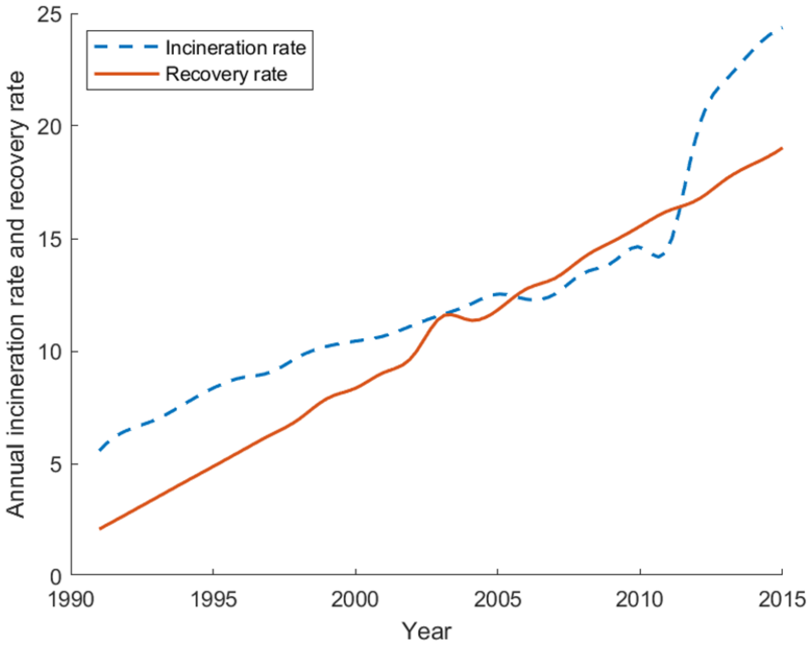

Fig.1 Global Plastic Incineration and Recycling Rates.

2.2 Optimal Environmental Bearing Capacity Model.

After analysis, the ten variables of the objective function selected in this paper are the respective output of HDPE, LDPE, PP, PS, PVC, PET, PUR, PP & A, and the recovery and incineration obtained from the recovery and incineration rates.

Build the objective function:

$$\max y = f(x) = AX - bx_9 - cx_{10} = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6 + a_7x_7 + a_8x_8 - bx_9 - cx_{10} \quad F(x) = nf(x)_{\max}$$

Where $y = f(x)$, represents the average environmental load level function, $F(x)$ represents the maximum environmental load level function; $A = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$ is the coefficient before polymer production, n represents the number of polymer types; $X = (x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8)'$ represents the output of 8 types of polymers, x_9 is the recovery amount, x_{10} is the amount of incineration.

Then, the coefficients of each variable of the objective function are solved. This paper chooses the analytic hierarchy process to determine the coefficient.

Modeling with analytic hierarchy process can be roughly performed in the following four steps:

(1) Establish a hierarchical structure model. The top layer is the target layer, with only one factor. The lowest layer is usually the scheme or object layer. There can be one or more levels in the middle, usually the level of guidelines or indicators.

(2) Construct all judgment matrices in each level. The pairwise comparison method and the 1-9 comparison scale are used to construct a pairwise comparison matrix until the lowest layer.

(3) Hierarchical ordering and consistency check. For each pairwise comparison matrix, calculate the maximum feature root and corresponding feature vector, and do consistency check:

$$\mathrm{CR} = \frac{CI}{RI}, CI = \frac{\chi_{\max} - n}{n-1}$$

If the test passes, the feature vector (after normalization) is the weight vector.

(4) Hierarchical total ranking and consistency check. Calculate the criterion layer weights, as shown in Figure 2:

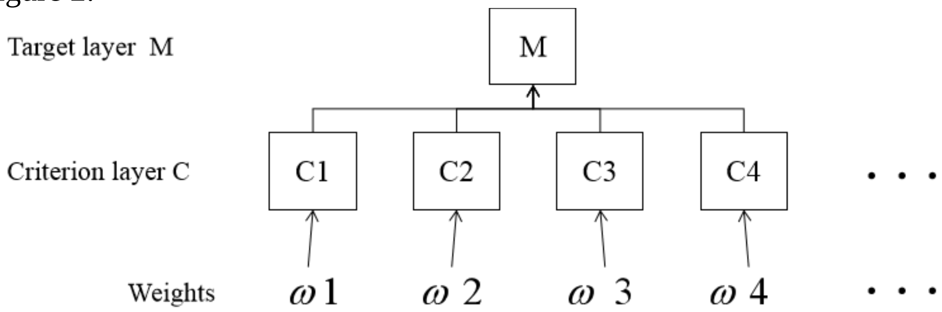

Fig.2 Analytic Hierarchy Diagram.

After the weights are determined by the analytic hierarchy process, the objective function is determined. Because the background object and its relationship of the model are fuzzy, that is, fuzzy mathematical model, this paper sets the constraint conditions and solves the optimal value based on the fuzzy extreme value of the bounded function under fuzzy constraints based on the fuzzy programming principle in fuzzy mathematics.

This problem belongs to a typical fuzzy programming problem. Solving it means not only satisfying the constraints to the greatest extent, but also achieving the objectives to the greatest extent.

Considering the maximum value of f under the C constraint, the model has the following definition:

Let the objective function $f: X \to R$ be a bounded function, $\mathrm{C} \in \mathrm{F(X)}$ is a fuzzy constraint, let $\mathrm{D{=}C} \cap \mathrm{M}_f$, unconditional fuzzy superior set with M_f as f. Call D the conditional fuzzy superior set under the f constraint, Let F(D) be the conditional fuzzy maxima of f under the C constraint. The seeking functions are:

$$\mathrm{M}_f(x) = \frac{f(x) - \min\left\{ f(x) \middle| x \in X \right\}}{\max\left\{ f(x) \middle| x \in X \right\} - \min\left\{ f(x) \middle| x \in X \right\}}$$

$$D(x) = C(x) \cap \mathrm{M}_f(x)$$

$$f(\mathrm{D})(y) = \cup\left\{ D(x) = \left(C(x) \cap \mathrm{M}_f(x) \right) \middle| f(x) = y \right\}$$

There are three steps to solving the conditional maximum of the objective function $f(x)$ under the fuzzy constraint C:

(1) Find the unconditional fuzzy superior set M_f.

(2) Find the conditional fuzzy superior set $\mathrm{D{=}C} \cap \mathrm{M}_f$.

(3) Find the optimal decision, that is, choose x^* such that $D(x^*) = max\left\{ D(x) \middle| x \in X \right\}$.

x^* is the conditional maximum point sought, and $f(x^*)$ is the conditional maximum under fuzzy constraint C.

3. Model Solving.

The objective function is:

$$\max y = f(x) = AX - bx_9 - cx_{10} = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6 + a_7x_7 + a_8x_8 - bx_9 - cx_{10}$$

$$F(x) = nf(x)_{\max}$$

The coefficients (weights) of each variable obtained through the analytic hierarchy process are:

Tab. 1 Table of coefficients for each variable

Symbol	Value
a_1	0.0879
a_2	0.0441
a_3	0.1101
a_4	0.1321
a_5	0.0662
a_6	0.0221
a_7	0.1543
a_8	0.1761
b	0.1145
c	0.0926

Keeping two or three significant digits, the solution of the objective function is:

$$y = f(x) = 0.088x_1 + 0.044x_2 + 0.110x_3 + 0.132x_4 + 0.066x_5 + 0.022x_6 + 0.154x_7 + 0.176x_8 - 0.115x_9 - 0.093x_{10}$$

Weighted sum is 1.

Set the constraint conditions according to the fuzzy extreme value of the bounded function under the fuzzy constraint, and solve the optimal value. Since recovery and incineration cannot be randomly generated, the solution objective function is transformed into

$$y = f(x_i) = a_i x_i, i = 1, 2, \cdots, 8$$

where a_i is the weight and x_i is the yield of each polymer.

Taking the output of 8 types of plastic polymers approximately obeying the normal distribution as a fuzzy constraint, let C's membership function be:

$$\mathrm{C}(x_i) = e^{-\frac{(x_i - \boldsymbol{\mu}_i)^2}{\sum_j (x_{ij} - \boldsymbol{\mu}_i)^2}}, X \in R, j = 1, 2, \cdots, n$$

The following results are obtained by calculation in this article:

$$\mu_i = (41.52, 34.56, 44.04, 17.2, 23.6, 22.6, 18.88, 28.28)$$

$$\sum_j (x_{ij} - \boldsymbol{\mu}_i)^2 = (4670.24, 2680.16, 4264.96, 602, 1618, 970, 1034.64, 3243.04), j = 1, 2, \cdots, 25$$

Solving the maximum environmental load level translates into finding the maximum value of the fuzzy condition of the objective function under constraints. (The maximum value for this question is also the maximum value.)

According to the known data, the current global waste generation has exceeded the environmental carrying capacity. The maximum value of the data is set to the maximum value of the bounded function, that is:

$$\sup f(x_i) = (5.804, 2.292, 7.376, 3.568, 2.448, 0.751, 4.939, 9.860), i = 1, 2, \cdots, 8$$

The value of $\sup f(x)$ varies with the value of *i*.

The minimum value is: $\inf f(x_i)=0$

Therefore, the equation holds: $M_f(x_i)=\dfrac{f(x_i)-0}{\sup f(x_i)-0}=\dfrac{f(x_i)}{\sup f(x_i)}$

The conditional fuzzy superior set of f under constraint condition C is:

$$C_f = C \cap M_f,\ C_f(x)=C(x)\cap M_f(x)$$

The conditional fuzzy extremum is $f(C_f)$, and its membership function is:

$$f(C_f)(y)=\bigcup_{x\in f^{-1}(y)}\left[D(x)=C(x)\cap M_f(x)\right]$$

Conditional optimal decision x^* satisfies $C_f(x^*)=\max C_f(x)$

Since the membership function curve of M_f is monotonically increasing, and C is a normally distributed fuzzy set, the fuzzy optimal decision of f under constraint C (that is, the maximum or maximum point of the fuzzy condition) is the root of the equation:

$$M_f(x_i)=C(x_i)=e^{-\frac{(x_i-\boldsymbol{\mu}_i)^2}{\sum_j (x_{ij}-\boldsymbol{\mu}_i)^2}}$$

It can be solved to obtain 8 optimal solutions, and the set is:

$$x^*=(60.8722, 48.4652, 62.1116, 24.6498, 34.4760, 31.4744, 29.0312, 49.0469)$$

It can be known from $C_f(x^*)=(0.9229, 0.9303, 0.9263, 0.9119, 0.9295, 0.9220, 0.9052, 0.8755)$ that the degree of acceptance of the constraint is in the range of 87.55% to 93.03%. At the same time, compared with the overall objective function, the superiority is also in this range.

The optimal solution of AX in the objective function can be obtained from $f(x^*)=a_i x^*$, that is, the average maximum environmental carrying capacity of the total polymer:

$$\max AX=\max\sum_i a_i x_i=\sum_i a_i x_i^*=33.6763$$

The optimal solution for the average environmental load can be obtained:

$$\max y = f(x)=\max\{AX-bx_9-cx_{10}\}=\max AX-\min\{bx_9+cx_{10}\}$$
$$=33.6763-(0.2535+0.8355)=32.5873(\textit{million metric tons})$$

Therefore, the maximum environmental carrying capacity is:

$$F(x)=nf(x)_{\max}=8*32.5873=260.6984(\textit{million metric tons})$$

Based on the above analysis, the world's largest environmental carrying capacity can be estimated at 260.7 million tons. According to the analysis data, the global waste generation volume was 255 million tons in 2003 and 265 million tons in 2004. In 2004, the estimated maximum value, which is the optimal value for environmental accommodation, has been exceeded. At present, according to data released by the United Nations Environment Programme in 2018, the annual amount of plastic waste generated around the world is about 300 million tons. A large amount of plastic waste enters the soil and the ocean, and eventually forms white pollution. In order to control the further intensification of white pollution, nearly 90 countries and regions around the world have introduced relevant policies and regulations to control or ban disposable non-degradable plastic products. The level of environmental safety varies from country to country, but in general, the amount of plastic waste generated should be controlled together below the warning line of the maximum environmental carrying level.

4. Conclusions.

In the question, this article constructs the objective function and uses the analytic hierarchy process to obtain the weights. Then we obtain the fuzzy extreme value of the objective function under the fuzzy constraints, so as to determine the maximum environmental load. A concerted effort by stakeholders to work together to mitigate the benefits of plastic reductions and move towards a society free of plastic pollution.

4.1 Strengths.

1) This article applies fuzzy programming theory to solve the fuzzy extreme value of the fuzzy constrained objective function and estimate the maximum environmental carrying capacity. This method is innovative. Due to the ambiguity of the background objects and their relationships in the model, the constraints are not accurate, and ordinary linear programming cannot get the answer. Through fuzzy programming, the conditional fuzzy superior set is determined, and the optimal result obtained is more practical to a certain extent.

2) According to the composition of the plastic polymer as the source, and the recovery amount and incineration amount as the variables to build the objective function, the index selection is more objective.

4.2 Weaknesses.

The form of the model is relatively single, the analytic hierarchy process is slightly subjective, and it cannot establish a functional relationship more effectively. The plastic production data of each country is difficult to obtain, so it is difficult to obtain specific reduction values about the maximum environmental carrying capacity of each country using fuzzy planning. It is not very precise.

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