ISSN 2616-5872 Vol.3, Issue 3: 33-42, DOI: 10.25236/AJEE.2021.030308

A Semi-Analytic Hierarchy Process to Assess the Plastic Waste and Contrive a Responsibility Index

Changtong Zhang[a], Lin Li[b], Shijie Zhou[c], Jiangpan Wang[d,*]

School of Financial Technology, Shanghai Lixin University of Accounting and Finance, Shanghai, China
[a]18603709182@163.com, [b]q1029113590@163.com, [c]Eternity315zsj@163.com, [d]pan623813@163.com

Abstract: *Currently, hundreds of millions of tons of plastic waste is produced every year around the world, which has caused irreversible and serious damage to the environment, which should be highly valued by all countries. Studies show that countries with fast growth and high economic levels produce more plastic waste than others. They should take the corresponding responsibility for the treatment of plastic waste. But so far, the responsibilities of all countries have no clear boundaries, which has caused the problem of plastic waste management to be delayed in reaching a global consensus. To handle the problem above, this paper adopts the semi-analytic hierarchy process (SAHP) based on the analytic hierarchy process (AHP). On the basis of the original model, a global share data processing method is used to replace the judgment matrix establishment process in the scheme layer, which reduces the influence of the subjective factors. It also improves the shortcomings that AHP cannot accommodate new samples. The SAHP helps to establish the responsibility index of each country through a responsibility quantification model system, which clearly quantifies the responsibility of each country, and provides an effective reference for the management of plastic waste in various countries.*

Keywords: *Plastic waste, Semi-analytic hierarchy process, Responsibility index, Environment protection*

1. Introduction

Since the invention of plastics, plastic products have continued to emerge, which have the advantages of strong plasticity, stability, and lightness. Compared with other materials, plastics are superior in raw material prices. After nearly a hundred years of development, plastic products have become an indispensable part of people's lives. While people enjoy the convenience of plastic products, plastic waste disposal is becoming a threat to the environment. In 2015, an estimated 55% of global plastic waste was discarded, which includes waste that goes to landfill (closed or open), is littered, or lost to the natural environment, 25% was incinerated, and only the rest of 20% was recycled.(Geyer R 2017) Most areas have varying degrees of inaction. Among them, East Asia and Pacific are the most serious, with unmanaged plastic waste as high as 60%.(Jambeck J R 2015) In addition to recycling, other treatment methods will cause a certain degree of damage to our environment. During the degradation process of plastic waste in landfills, CH4, CO2 and various 21 mixtures of pollutants are generated in a large quantity, which exacerbate the greenhouse effect.(Kumar S 2004) Incineration will cause a lot of dust to be scattered in the air and emit toxic gases.(Wey M Y 2006) From this point of view, it is very necessary to control the production of plastic products from the source, while requiring each country to bear the corresponding responsibility for the plastic waste in the country.

Scholars are cooperating with governments of various countries, hoping to propose a reasonable solution to the plastic waste problem. Qiao Huang and Guangwu Chen (2020) analyzed China's policy of banning the import of most plastic waste in January 2018, and investigated the increasing demand for waste disposal capacity in other economies. Through ecological network analysis, they identified the dominant controller of the global plastic waste trading network, including the United States, the European Union, Germany and China.(Huang Q 2020) From another aspect, Zhang Jiayu and Liu Qing (2019) reviewed the relevant legislation and actions on plastic pollution in different countries and regions. By comparing the legislation of different countries on marine plastics and microplastics, they put forward suggestions and proposals to make up for the deficiencies of Chinese legislation.(Zhang J Y 2019)

Moreover, Ashok V. Shekdar (2009) took a multi-pronged, comprehensive improvement approach to achieve sustainability. He named this approach Solid Waste Management (SWM), which can be tailored to specific circumstances of the target country. Until today, more and more experts have shared the same opinion that whoever ties the bell around the tiger's neck must untie it.(Shekdar A V 2009) A Fråne, Å

ISSN 2616-5872 Vol.3, Issue 3: 33-42, DOI: 10.25236/AJEE.2021.030308

Stenmarck (2014) investigated the policies and behaviors of different countries in the Nordic region to deal with plastic pollution. He pointed out that countries with different plastic waste output situations should have different policies and programs.

After then, Ebo Tawiah Quartey and Hero Tosefa (2015) analyzed the impact of plastic use and disposal of plastic waste in Ghana and emphasized the importance of managing the responsibilities of different producers.(Quartey E T 2015) Later, Walter Leal Filho and Ulla Saari (2019) discussed the role of the Extended Producer Responsibility System in dealing with plastic waste, and provided some schemes for plastic waste disposal to help enhance the extension of producer responsibility.(Leal Filho W 2019) Likewise, in the field of waste management, Tot B, Srđević B, and Vujić B (2016) used AHP (analytic hierarchy process) to select the waste management factors, determine the degree and weight of its impact on waste output and develop a sustainable waste management system in Serbia.(Tot B 2016)

Similarly, inspired by the above, in this paper, a semi-analytic hierarchy process (SAHP) aiming at the responsibility index in different countries and regions is proposed, which is only the target layer and criterion layer and no scheme layer. Instead, a global share data processing method is applied to quantify the responsibilities of different countries. SAHP is an evaluation model based on AHP (analytic hierarchy process), which can solve complex problems with multiple factors through a combination of qualitative and quantitative analysis methods.(Arukala S R 2019) Like AHP, SAHP also determines the weight of the target occupied by the influencing factors by constructing a judgment matrix.(Xu S 2019) In this paper, the responsibility index established through the SAHP can identify countries that are poor-performed and well-performed in plastic waste management, and provide references for countries to formulate new policies on plastic waste management.

2. The SAHP Evaluation Model

2.1. Model Proposition

Countries with a fast development speed and a high degree of development produce more plastic waste annually than other countries, and these countries should also take more responsibility for the environmental pollution caused by the disposal of plastic waste. To solve the global problem of responsibility distribution, this paper intends to establish an evaluation model to quantify the responsibilities that countries should bear. To simplify the problem and establish a model, this paper fully considers the various environmental impacts of different plastic waste disposal methods and the gaps in the economic conditions of various countries, and thus selects five evaluation indicators to evaluate the responsibilities of each country.

In the choice of model, it is of necessity to combine qualitative and quantitative analysis to analyze the problem from multiple angles. Meanwhile, as the research is aimed at the quantification of responsibility in various countries around the world, it puts forward a high requirement for the accuracy of the results. For some common evaluation models, such as Principal Component Analysis (PCA), the evaluation process of linear combination of original variables to reduce dimension is not suitable for the index system developed in this paper. Another example is the gray correlation analysis method, which has strict requirements on the time series characteristics of sample data, and its evaluation results do not reflect absolute levels, but relative values, which makes it unsuitable for the goal of quantification of responsibility. The BP neural network comprehensive evaluation method (ANN) can weaken the human factors in the weight determination process and eliminate the insignificant factors simultaneously, which is crucial to the improvement of the evaluation effect. However, due to its extremely weak interpretability and extremely high requirements in training the sample size, this evaluation method is not suitable for the problem studied in this paper. Through comprehensive consideration of multiple evaluation models, this paper finally believes that the analytic hierarchy process (AHP) has certain feasibility for the problem of quantification of responsibility.

AHP is suitable for most of the decision-making problems in daily life. According to the nature of the problem and the goal to be achieved, it divides the problems that need decision-making into multiple levels and aggregates them to form a multi-level structure model to evaluate those problems that are difficult to solve with quantitative methods. For the problem of quantifying the responsibilities of various countries in the world, its qualitative and quantitative analysis methods and diverse model structure have obvious advantages. But it also has shortcomings that cannot be ignored such as the fact that it relies on subjective judgment thinking in the process of establishing the judgment matrix at the criterion layer and the scheme layer, and its subjectivity is relatively strong. At the same time, AHP cannot adapt to new samples well, and it cannot add new samples without changing the evaluation results of the original samples.

For the problem studied in this paper, the subjectivity in the evaluation process of using AHP to evaluate the responsibility index of each country cannot be ignored. After the evaluation results of some countries or regions are obtained, if a new country or region is evaluated, the previous evaluation results of the original sample set will be changed, which greatly reduces the evaluation effect and efficiency. In order to make this method more suitable for quantifying the responsibilities of countries in the world, this paper has made corresponding improvements and innovations, and proposed the semi-analytic hierarchy process (SAHP).

2.2. Model Introduction

Different from AHP, SAHP established in this paper does not have a scheme layer, instead it is a specific data processing method. Compared with AHP, SAHP's handling of samples reduces the time complexity and subjectivity of its evaluation to a certain extent, and SAHP can better accept new samples, that is, adding new samples without changing the original sample evaluation results, which improves the evaluation effect and efficiency of the model. This is in line with the original research purpose, to extend the use of SAHP to various countries and establish their own quantitative indicators.

In view of the complex and excessive factors affecting plastic waste in reality, five predictors of plastic waste are selected to simplify the problem. The five predictors, carbon dioxide emissions(C_e), sum of microplastics and macroplastics in the surface ocean(M_a), a country's gross domestic product(G), global population(P), marine and freshwater vitality index(L_i), are related to the amount of plastic waste, which are selected as criteria for the criterion layer. Therefore, the weight corresponding to each factor were obtained. Then global share matrix is gained through data analysis and processing of various national factors. For each country or region, the sum of the product of the global share of each factor and the weight corresponding to that factor is the result of quantifying the responsibility of their country or region. The results of quantified liability are called the responsibility index.

2.3. Model Construction

For these five factors, which are very relevant to our research goals, population growth was selected first, which partly reflects the demands of plastic product in each country. Second, GDP was chosen, which mirrors the amount of plastic waste generated in each country and explains the effectiveness of the treatment of plastic waste.(Wang B 2020) Third, carbon dioxide emissions were deemed to reflect the impact of plastic incineration. Then, the total amount of microplastics and macroplastics in the surface ocean were treated to quantify the effect of the plastic waste discharge.(Lebreton L 2019) Finally, marine and freshwater vitality index was used to quantify the extent of the current marine plastic problem. (Kenward M 2018) The selection of these indicators fully considers the various environmental impacts of different plastic waste treatment methods and the gaps in the economic conditions of various countries on the premise of simplifying the problem. Besides, the data for all of these factors comes from the World Bank, Our World In Data and World Wide Fund. Their data are authoritative and comprehensive, which greatly reduces the result error while catering to our model.

2.3.1. Hierarchical Structure

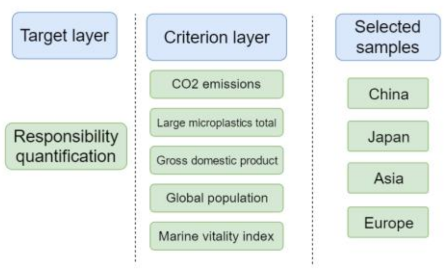

Figure 1: Hierarchical structure.

2.3.2. Construction of Judgment Matrix

When determining the weights between factors at various levels, if it is only a qualitative result, it is often not easy to be accepted by others, so consistent matrix method, that is: not to compare all factors

ISSN 2616-5872 Vol.3, Issue 3: 33-42, DOI: 10.25236/AJEE.2021.030308

together, but compare with each other, is applied into the paper. Relative scales are used in the comparison to reduce the difficulty of comparing different factors with different properties as much as possible to improve accuracy.(Liu W L 2005) In this paper, in view of the complexity of each influencing factor, a scale category with the most detailed relative importance classification is selected, that is, the scale table is derived from Saaty Scaling Law of Thomas L. Saaty.

Table 1: Numerical setting standard group.

Scale	Meaning
1	The two factors are of equal importance
3	The former is slightly more important than the latter
5	The former is obviously more important than the latter
7	The former is more important than the latter
9	The former is extremely important than the latter
2,4,6,8	The median value of the above adjacent judgment

Fill the *i-th* and *j-th* columns of the matrix with the scale between the different factors, and the judgment matrix ***A*** (positive and inverse matrix) can be obtained:

$$\boldsymbol{A}=\begin{pmatrix} a_{11} & \cdots & a_{15} \\ \vdots & \ddots & \vdots \\ a_{51} & \cdots & a_{55} \end{pmatrix}=\begin{pmatrix} 1 & 2 & 3 & 4 & 8 \\ \frac{1}{2} & 1 & 2 & 3 & 6 \\ \frac{1}{3} & \frac{1}{2} & 1 & 2 & 4 \\ \frac{1}{4} & \frac{1}{3} & \frac{1}{2} & 1 & 2 \\ \frac{1}{8} & \frac{1}{6} & \frac{1}{4} & \frac{1}{2} & 1 \end{pmatrix} \tag{1}$$

Where:

A is a judgment matrix.

a_{ij} is a scale marker, $a_{ij}\in[1/9,9]$, $i,j\in[1,5]$.

Use the normalized column average method to find the weight:

Step 1: Find the sum of each column of the comparison matrix.

Table 2: Scale of influencing factors.

	C_e	M_a	L_i	P	G
C_e	1	2	3	4	8
M_a	1/2	1	2	3	6
L_i	1/3	1/2	1	2	4
P	1/4	1/3	1/2	1	2
G	1/8	1/6	1/4	1/2	1
Sum of column	53/24	4	27/4	21/2	21

Step 2: Divide each element of the pairwise comparison matrix by the sum of its corresponding columns, and the new matrix $\boldsymbol{A_s}$ formed by the quotient is called the standard pairwise comparison matrix.

$$\boldsymbol{A_s}=\begin{pmatrix} a_{11} & \cdots & a_{15} \\ \vdots & \ddots & \vdots \\ a_{51} & \cdots & a_{55} \end{pmatrix}=\begin{pmatrix} \frac{24}{53} & \frac{1}{2} & \frac{4}{9} & \frac{8}{21} & \frac{8}{21} \\ \frac{12}{53} & \frac{1}{4} & \frac{8}{27} & \frac{2}{7} & \frac{2}{7} \\ \frac{8}{53} & \frac{1}{8} & \frac{4}{27} & \frac{4}{21} & \frac{4}{21} \\ \frac{6}{53} & \frac{1}{12} & \frac{2}{27} & \frac{2}{21} & \frac{2}{21} \\ \frac{3}{53} & \frac{1}{24} & \frac{1}{27} & \frac{1}{21} & \frac{1}{21} \end{pmatrix} \tag{2}$$

Step 3: Calculate the average of each row of the pairwise comparison matrix. These averages are the weights of each factor.

ISSN 2616-5872 Vol.3, Issue 3: 33-42, DOI: 10.25236/AJEE.2021.030308

Table 3: Weight table of each factor.

	C_e	M_a	L_i	P	G	Row average
C_e	24/53	1/2	4/9	8/21	8/21	0.4318
M_a	12/53	1/4	8/27	2/7	2/7	0.2688
L_i	8/53	1/8	4/27	4/21	4/21	0.1610
P	6/53	1/12	2/27	2/21	2/21	0.0922
G	3/53	1/24	1/27	1/21	1/21	0.0461

$$\boldsymbol{W}=\begin{pmatrix}w_1\\ \vdots\\ w_5\end{pmatrix}\begin{pmatrix}0.4318\\0.2688\\0.1610\\0.0922\\0.0461\end{pmatrix} \tag{3}$$

Where:

$\boldsymbol{W}$ is a weight vector.

w_i is a weight of factors, $w_i \in [0,1]$, $i \in [0,5]$.

Then we get the weights of 5 factors:

The weight of the carbon dioxide emissions C_e = 0.4318.

The weight of the marine and freshwater vitality index M_a = 0.2688.

The weight of the sum of microplastics and macroplastics in the surface ocean L_i = 0.1610.

The weight of a country's gross domestic product P = 0.0922.

The weight of a global population G = 0.0461.

2.3.3. Consistency Test

In order to test the coordination between the relative importance of each factor, a consistency test is performed here:

$$\boldsymbol{A}\times\boldsymbol{W}=\begin{pmatrix}a_{11} & \cdots & a_{15}\\ \vdots & \ddots & \vdots\\ a_{51} & \cdots & a_{55}\end{pmatrix}\begin{pmatrix}w_1\\ \vdots\\ w_5\end{pmatrix}=\begin{pmatrix}b_1\\ \vdots\\ b_5\end{pmatrix}=\begin{pmatrix}2.1903\\1.3601\\0.8082\\0.4625\\0.2313\end{pmatrix} \tag{4}$$

From the above formula, the maximum characteristic root λ can be calculated:

$$\lambda=\frac{1}{n}\sum_{i=1}^{n}\frac{b_i}{w_i}=\frac{\left(\frac{2.1903}{0.4318}+\frac{1.3601}{0.2688}+\frac{0.8082}{0.1610}+\frac{0.4625}{0.0922}+\frac{0.2313}{0.0461}\right)}{5}=5.0364 \tag{5}$$

This paper performs consistency test through the consistency indicator CI:

$$CI=\frac{\lambda-n}{n-1}=\frac{5.0364-5}{5-1}=0.0091 \tag{6}$$

Table 4: Randomly consistent RI index values of different matrix dimensions.

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

From this, the consistency ratio CR is calculated:

$$CR=\frac{CI}{RI_{(n=5)}}=\frac{0.0091}{1.12}=0.0081<0.1 \tag{7}$$

Therefore, the degree of inconsistency of $\boldsymbol{A}$ is within the allowable range and passes the consistency

ISSN 2616-5872 Vol.3, Issue 3: 33-42, DOI: 10.25236/AJEE.2021.030308

check.

2.3.4. Responsibility Standard

1) The smaller the value of L_i (global marine and freshwater vitality index) is, the more seriously plastic waste of the region discharged destroys to oceans and rivers. Therefore, this region should take more responsibilities.

2) The bigger the value of C_e (global carbon dioxide emissions) is, the higher plastic waste incineration of the region is. Therefore, the region should take more responsibilities.

3) The bigger the value of M_a (global shares of microplastics and macroplastics in the surface ocean) is, the more coastal plastic waste will generate. Therefore, the region should take more responsibilities.

4) The bigger the value of P (global population) is, the more requirements for plastic production of the region are. Therefore, the region should take more responsibilities.

5) The bigger the value of G (a country's gross domestic product) is, the higher regional development level will be. It indicates that the region has greater capacity to handle garbage. Therefore, the region should take more responsibilities.

2.3.5. Responsibility Index

Different from the way that AHP calculates the weight of the sample (Zhang Z 2013), this paper takes a global share data processing method, calculates the share of each factor, and builds a T matrix based on this. The value of C_e' (share of global carbon dioxide emissions), M_a' (share of global microplastics and macroplastics in the surface ocean), L_i' (global marine and freshwater vitality index proportion), P' (share of global population), G' (share of global gross domestic product) are required to be collected to quantify the corresponding responsibility of a certain region, which symbolize the corresponding global share. Different from other factors, which are positively correlated with the results, L_i is negatively correlated with the result, that is, the greater L_i is, the lighter the responsibility of the state should take. Therefore, we take the inverse of L_i' and construct a row vector of $\boldsymbol{T}$.

$$\boldsymbol{T} = \left[C_e', M_a', \frac{1}{L_i'}, P', G'\right] \tag{8}$$

Where:

$\boldsymbol{T}$ is a global share matrix.

The corresponding quantified Responsibility index R can be achieved by multiplying the value obtained with its corresponding proportion and multiplying by 100.

$$R = 100 \times \boldsymbol{T} \cdot \boldsymbol{W} = [C_e'W_1 + M_a'W_2 + \frac{W_3}{L_i'} + P'W_4 + G'W_5] \times 100 \tag{9}$$

Where:

R is a quantified corresponding responsibility index of a certain region.

3. Model Application and Validation

3.1. Data Description

The original data come from the World Bank, Our World In Data and World Wide Fund. Since the data are open sources and published authoritatively, it only takes one more step to use. Under the premise of ensuring accurate and real-time data, the experimental data was adopted from 2014, because in recent years, part of the original data has not been completely collected.

3.2. Experimental Result

Through the unified processing of the data, the following experimental results can be obtained by substituting it into the responsibility index formula in the above paper.

ISSN 2616-5872 Vol.3, Issue 3: 33-42, DOI: 10.25236/AJEE.2021.030308

Table 5: Specific values of various factors in 2014 (Integers).

	C_e(million tons)	M_a(tons)	L_i(points)	P	G(billion dollars)
China	10292	106319	33	1364270000	10439
Japan	1214	17011	64	127276000	4850
Asia	14272	193308	31	2267482299	21900
Europe	3242	98959	67	508193856	18700
World	36138	1303300	41	7255653881	79333

The quantified corresponding responsibility of China and Japan:

$$\boldsymbol{T}_C = [0.2848, 0.0816, 1.2424, 0.1880, 0.1316] \quad (10)$$

$$R_C = 100 \times \boldsymbol{T}_C \cdot \boldsymbol{W} = 100 \times \begin{pmatrix} 0.2848 \\ 0.0816 \\ 1.2424 \\ 0.1880 \\ 0.1316 \end{pmatrix}^T \begin{pmatrix} 0.4318 \\ 0.2688 \\ 0.1610 \\ 0.0922 \\ 0.0461 \end{pmatrix} = 36.8364 \quad (11)$$

$$\boldsymbol{T}_J = [0.0336, 0.0131, 0.6406, 0.0175, 0.0611] \quad (12)$$

$$R_J = 100 \times \boldsymbol{T}_J \cdot \boldsymbol{W} = 100 \times \begin{pmatrix} 0.0336 \\ 0.0131 \\ 0.6406 \\ 0.0175 \\ 0.0611 \end{pmatrix}^T \begin{pmatrix} 0.4318 \\ 0.2688 \\ 0.1610 \\ 0.0922 \\ 0.0461 \end{pmatrix} = 12.5598 \quad (13)$$

Where:

$\boldsymbol{T}_C$ is the China share matrix. R_C is the China responsibility index.

$\boldsymbol{T}_J$ is the Japan share matrix. R_J is the Japan responsibility index.

The quantified corresponding responsibility of Aisa and Europe:

$$\boldsymbol{T}_A = [0.3949, 0.1483, 1.3226, 0.3125, 0.2761] \quad (14)$$

$$R_A = 100 \times \boldsymbol{T}_A \cdot \boldsymbol{W} = 100 \times \begin{pmatrix} 0.3949 \\ 0.1483 \\ 1.3226 \\ 0.3125 \\ 0.2761 \end{pmatrix}^T \begin{pmatrix} 0.4318 \\ 0.2688 \\ 0.1610 \\ 0.0922 \\ 0.0461 \end{pmatrix} = 46.4913 \quad (15)$$

$$\boldsymbol{T}_E = [0.0897, 0.0759, 0.6119, 0.0700, 0.2357] \quad (16)$$

$$R_E = 100 \times \boldsymbol{T}_E \cdot \boldsymbol{W} = 100 \times \begin{pmatrix} 0.0897 \\ 0.0759 \\ 0.6119 \\ 0.0700 \\ 0.2357 \end{pmatrix}^T \begin{pmatrix} 0.4318 \\ 0.2688 \\ 0.1610 \\ 0.0922 \\ 0.0461 \end{pmatrix} = 17.5008 \quad (17)$$

Where:

$\boldsymbol{T}_A$ is the Asia share matrix. R_A is the Asia responsibility index.

$\boldsymbol{T}_E$ is the Europe share matrix. R_E is the Europe responsibility index.

Through SAHP, the responsibility indexes of China, Japan, Europe and Asia can be achieved: R_C = 36.8364, R_J = 12.5598, R_E = 17.5008, and R_A = 46.4913. Taking China and Japan as an analogy, it can be found that China's score is more than twice as high as Japan's, indicating that China should take more responsibility for the consequences of producing excessive plastic waste and damaging the environment.

Taking the actual situation of China and Japan into the responsibility index, we can find that China's

GDP is higher than that of Japan, and its ability to handle plastic waste is higher. The larger the population, the more demands for plastic, while the carbon dioxide production, large sea level, and the amount of microplastics are much higher than those of Japan, and the marine vitality index is much lower than Japan, indicating that China has caused relatively large damage to the environment due to the manufacture of excessive plastic waste. Obviously, China should bear more responsibilities than Japan, which is the same as that obtained by the above model. The results obtained by SAHP are consistent with reality.

3.3. Model Comparison

In order to verify the pros and cons of SAHP and AHP, this paper uses AHP to quantify the responsibilities of countries and regions again, and compares the results of the two methods. The hierarchical structure of AHP is shown below:

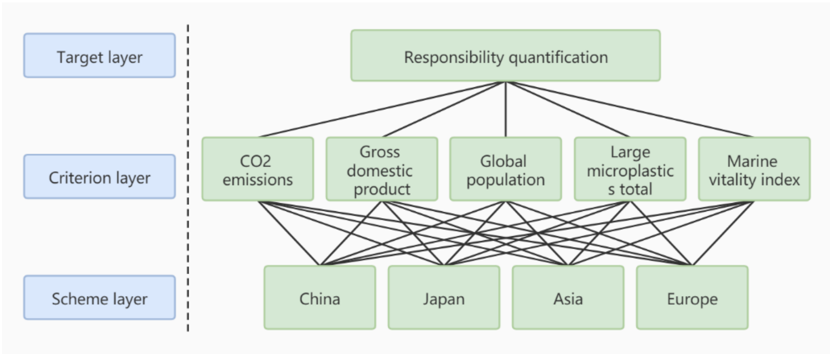

Figure 2: Hierarchical structure of AHP.

The weight vector ***W***, the weight of five factors in criterion layer obtained by AHP, is the same as those obtained by SAHP. The weight of the regions and countries in the scheme layer based each factor in criterion layer can be obtained in AHP, which is the weight vector ***P***. The calculation process of the weight vector ***P*** is the same as that of the weight vector ***W***, so it is omitted here. For there are five factors, so the results are five weight vectors ***P***, all of which are 4 multiply 1 in size. They are concatenated into the weight matrix ***S***, which is 4 multiply 5 in size. The quantified corresponding responsibility matrix can be expressed by the following formula:

$$\boldsymbol{R}' = 100 \times \boldsymbol{S} \cdot \boldsymbol{W} =$$

$$100 \times \begin{pmatrix} 0.3547 & 0.2558 & 0.3254 & 0.3197 & 0.1860 \\ 0.0418 & 0.0409 & 0.1678 & 0.0298 & 0.0877 \\ 0.4918 & 0.4651 & 0.3464 & 0.5314 & 0.3918 \\ 0.1117 & 0.2381 & 0.1603 & 0.1191 & 0.3345 \end{pmatrix} \times \begin{pmatrix} 0.4318 \\ 0.2688 \\ 0.1610 \\ 0.0922 \\ 0.0461 \end{pmatrix} = \begin{pmatrix} 31.2419 \\ 6.2839 \\ 46.0268 \\ 16.4474 \end{pmatrix} \tag{18}$$

Responsibility index of China $R_C = 31.2419$.

Responsibility index of Japan $R_J = 6.2839$.

Responsibility index of Asia $R_A = 46.0268$.

Responsibility index of Europe $R_E = 16.4474$.

In this paper, the sample size selected in this paper is small and does not conform to the normal distribution. Therefore, the Wilcoxon signed rank test is performed on two sets of paired samples. The test result obtained is as follows:

$$P = 0.068 > 0.05 \tag{19}$$

Where:

P is a significance testing with two-tailed.

The significance level $\alpha = 0.05$.

According to the results, it can be rejected that the paired samples are different, that is, the results obtained by SAHP and AHP are not significantly different.

In the case of the same effect of AHP and SAHP, SAHP only needs to construct the judgment matrix once that makes its time complexity lower. Besides, SAHP without scheme layer can better accommodate new samples. By contrast, AHP cannot add new samples without changing the responsibility index of the previous samples (Ishizaka A. 2011). Consequently, SAHP has a better evaluation effect.

4. Conclusions and Discussions

This paper proposes a semi-analytic hierarchy process (SAHP) to represent the responsibility indicators of different countries and regions. In the above example, the responsibility indexes of the two countries and regions are derived: China should bear more responsibility than Japan to control the amount of plastic waste. Asia should also take more responsibility to control plastic waste than Europe. Under the condition of ensuring that the data is true and valid, SAHP can be used worldwide to calculate the responsibility of each country. Through the calculated scores, government agencies such as environmental management agencies can adjust their plastic waste control policies based on their ranking in the world. On the other hand, WHO can refer to these standards to judge the disposal of plastic waste in various countries. At the same time, the level of investment in environmental protection in different countries can also be reflected by the annual changes in the responsibility index.

To address the issue of quantifying global responsibility, SAHP combines qualitative and quantitative methods to solve complex system problems. In the criterion layer, 5 factors make the weight determination process simpler and reduce inconsistencies, which makes its evaluation results more accurate. On the other hand, SAHP based on AHP does not exist scheme layer, which means that it can avoid the disadvantages of not being able to generate new solutions. For a new solution, only a simple data processing is needed to multiply it with the weight vector $\boldsymbol{W}$ to quantify it. Through the $\boldsymbol{W}$ matrix, the degree of influence of each factor is calculated. In these results, the top two influence levels are carbon dioxide emissions $C_e = 0.4318$ and the marine and freshwater vitality index $M_a = 0.2688$, which warns that government agencies should pay more attention to the carbon emissions caused by plastic waste, such as incineration, and the destruction of Marine freshwater vitality Index by the indiscriminate dumping of plastic waste in the ocean by ships. Relatively speaking, SAHP also has some weaknesses. In order to better solve the problem of global plastic waste-related responsibilities, the global share data processing methods is applied, which limits the scope of SAHP. In addition, although SAHP greatly reduces subjectivity compared to AHP, there is still a certain degree of subjectivity. In these aspects, SAHP needs to be optimized.

Acknowledgement

This research was supported by the construction funds for the application-oriented undergraduate pilot program in Shanghai universities: Financial Engineering (Finance Technology) B1-12-2801-19-0001Z.

References

[1] Geyer R, Jambeck J.R, Law K.L. 2017. "Production, use, and fate of all plastics ever made." Science Advances 3(7).
[2] Jambeck J R, Geyer R, Wilcox C, et al. 2015. "Plastic waste inputs from land into the ocean." Science 347(6223): 768–771.
[3] Kumar S, Gaikwad S A, Shekdar A V, et al. 2004. "Estimation method for national methane emission from solid waste landfills." Atmospheric environment 38(21): 3481–3487.
[4] Wey M Y, Liu K Y, Tsai T H, et al. 2006. "Thermal treatment of the fly ash from municipal solid waste incinerator with rotary kiln." Journal of hazardous materials 137(2): 981–989.
[5] Huang Q, Chen G, Wang Y, et al. 2020. "Modelling the global impact of China's ban on plastic waste imports." Resources, Conservation and Recycling 154: 104607.
[6] Zhang J X, Liu Q, Zhang C L, et al. 2019. "Research on the legislation of marine plastics and micro-plastics management." Marine Environmental Science 38(02): 167–177.
[7] Shekdar A V. 2009. "Sustainable solid waste management: an integrated approach for Asian countries." Waste management 29(4): 1438–1448.
[8] Quartey E T, Tosefa H, Danquah K A B, et al. 2015. "Theoretical framework for plastic waste management in Ghana through extended producer responsibility: case of sachet water waste." International journal of environmental research and public health 12(8): 9907–9919.

ISSN 2616-5872 Vol.3, Issue 3: 33-42, DOI: 10.25236/AJEE.2021.030308

[9] Leal Filho W, Saari U, Fedoruk M, et al. 2019. "An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe." Journal of cleaner production 214: 550–558.
[10] Tot B, Srđević B, Vujić B, et al. 2016. "Evaluation of key driver categories influencing sustainable waste management development with the analytic hierarchy process (AHP): Serbia example." Waste Management & Research 34(8): 740–747.
[11] Arukala S R, Pancharathi R K, Pulukuri A R. 2019. "Evaluation of Sustainable Performance Indicators for the Built Environment Using AHP Approach." Journal of The Institution of Engineers (India): Series A 100(4): 619–631.
[12] Xu S, Xu D, Liu L. 2019. "Construction of regional informatization ecological environment based on the entropy weight modified AHP hierarchy model." Sustainable Computing: Informatics and Systems 22: 26–31.
[13] Wang B. 2020. "Investigating network structure of cross-regional environmental spillover effects and driving factors." Journal of the Air & Waste Management Association 70(3): 243–252.
[14] Lebreton L, Egger M, Slat B. 2019. "A global mass budget for positively buoyant macro-plastic debris in the ocean." Scientific reports 9(1): 1–10.
[15] Kenward M. 2018. "Plastic waste is the last straw, says UK." MRS Bulletin 43(12): 913–914.
[16] Fråne A, Stenmarck Å, Gíslason S, et al. 2014. "Collection & recycling of plastic waste: Improvements in existing collection and recycling systems in the Nordic countries." Nordic Council of Ministers.
[17] Liu W L, Liu S Y. 2005. "Construction of the judgement matrix of group decision-making in AHP." Systems Engineering & Electronics 27(11): 1907–1908.
[18] Zhang Z, Wei C. 2013. "Summary of Some Theories and Applications in AHP." Journal of Qufu Normal University (Natural Science) 39(01):37–41.
[19] Ishizaka A, Balkenborg D, Kaplan T. 2011. "Does AHP help us make a choice? An experimental evaluation." Journal of the Operational Research Society 62(10): 1801–1812.