

## Models for EDPs Relocation and Relative Policies

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### Abstract

The aim of this paper is to explore the problem of environmentally displaced persons (EDPs) which are forced to migrate. In the future, the number of EDPs will increase. In the process of their migration, many factors need to be considered, such as how to choose recipient country, how to protect EDPs' rights and culture, and how to provide policy support. Therefore, we establish mathematical models to analyze the problems mentioned above. Firstly, we predict the future population of EDPs. We establish the relationship among the global CO<sub>2</sub> concentrations, temperature and sea level. By curve fitting method, we process the data of global CO<sub>2</sub> concentrations over the past 60 years to make a series of predictions which about CO<sub>2</sub> concentrations, temperature and sea level for the next 100 years. Then we divide the global sea into 9 regions to estimate the sea level rising. To collect the average elevation of the lower countries in each region and compare it with the rising level, we can forecast countries which will be submerged. Combining the population size and growth rate, we can draw the estimation that EDPs will reach 140,000,000 in the next 100 years. Secondly, we analyze the risk of cultural loss in the process of environmentally displaced persons' displacement. From three aspects: the value of culture itself, the influence of recipient country on culture and the international protection of culture. we divide the three aspects into eight factors. By consulting the data, the influence degree of each factor was compared, the weight of each factor was calculated by using Analytic Hierarchy Process, and then calculate the scores of recipient countries from the perspective of cultural loss risk with Principal Component Analysis, so that the appropriate recipient country could be selected according to the score for better cultural protection. Thirdly, we point out the importance and necessity of protecting human rights and culture and propose protection policies. In terms of human rights, we select several basic human rights out of many human rights, focusing on the rights that must be guaranteed such as food, medical care, education, equality and speech of the displaced. In terms of culture, it is explained from three aspects: cultural inheritance, uniqueness and influence. Considering the protection of human rights and culture and the maximization of loss reduction, we carry out Multi-objective Programming, formulate six refugee protection policies, and evaluated the target measurement and degree with the goal-oriented model to assess the potential impact after the implementation of the policy. Finally, we improve the strategies and indicate the importance of policy implementation. The impact of the policies needs to be tracked in real time. And by using side-effect assessment model, we can considerate potential effects thoroughly. Based on the negative impact of the assessment, the proposed policy should be revised to increase the positive impact. Then the significance of implementing the proposed policies is illustrated by a series of data from three aspects: before, during and after migration.

### Keywords

Curve fitting, Analytic Hierarchy Process, Multi-objective Programming, Principal Component Analysis.

## 1. Introduction

### 1.1. Background

As global temperatures and sea levels rise, most low-altitude countries and regions, such as the Maldives and some south Pacific island countries, are at risk of being submerged. If the territory of country is submerged, the population of this country will be forced to migrate and leave their homeland in search of new homes, becoming environmentally displaced persons.

These EDPs will face many difficulties and problems through the process of their migration. For example, how to make a regulation that countries around the world undertake the responsibility of receiving EDPs, how to maximize the retention of EDPs' specific culture, how to guarantee the basic human rights of EDPs in the recipient country and so on.

To solve these problems, the international and national levels have proposed a series of protection policies. The potential impact of the proposed policy is analyzed and then according to negative effects the proposed policies are improved. The importance of policies is reflected. We analyze the positive impact of the proposed policies to reflect the importance of policy implementation.

### 1.2. Restatement of the Problem

First, we analyze the topic. We need to determine the future population of EDPs and the risk of cultural loss. After considering the risks, we put forward the policy to protect EDPs, including the protection of human rights and culture. We use Multi-objective Programming to formulate relevant policies. After the policy is issued, it will have an impact on the countries of climate refugees and host countries. We will intervene in the impact content to reduce side effects and increase positive effects.

When analyzing the number of potential EDPs, we first looked for the change of global carbon dioxide concentration since 1948, estimated the carbon dioxide concentration to 2100 by curve fitting, and analyzed the global temperature change under the greenhouse effect by carbon dioxide concentration. By using the sea level prediction equation proposed by Wigeley et al. to link temperature change, greenhouse effect intensity and ocean heat diffusion, the prediction model of future sea level change was obtained, and the rise prediction of 9 sea areas in the world in the next few decades was calculated. Finally, according to the altitude of each country, the flood risk countries are found and the number of EDPs is predicted.

We will assess the risk of cultural loss and identify the best countries to relocate. We divide the risk of cultural loss into 8 major factors, assign importance to them, use Analytic Hierarchy Process to calculate the weight, and use Principal Component Analysis to quantify the score of each influencing factor in the place of migration, so as to find out the most suitable country for EDPs to migrate.

We use Multi-objective Programming to propose six policies for the protection of EDPs, and use the goal-oriented model to measure and evaluate the goals and degrees: first define a quantifiable standard in each policy, then measure the actual value of the standard, and finally carry out potential impact analysis. After the analysis, we use the side effect assessment model to conduct real-time tracking and investigation of the conditions in the implementation process, so as to achieve the purpose of dynamic modification of the policy.

### 1.3. Our Work

Estimate the number of EDPs in the future, based on the variation tendency of global CO<sub>2</sub> concentration, temperature and sea level.

Assess the risk of cultural loss in migration by taking into account the value of the culture, the recipient country and the international influence.

Propose the policies and evaluate it, aiming at human rights protection and cultural protection.

After the policies are implemented, pay attention to the negative effect. Then improve the proposed policy and explain the importance of policy protection.

## 2. Simplifying Assumption

- (1) Assume that the EDPs are those who are forced to migrate due to rising sea levels.
- (2) Assume that when the island country is flooded, part of the EDPs evacuate and eventually the whole country is relocated.
- (3) Assume that when sea level rises higher than the average elevation of a country, the country will be flooded.

## 3. Notation

| Symbols  | DEfinition                                     |
|----------|------------------------------------------------|
| $C(t)$   | CO <sub>2</sub> concentrations change          |
| $F(t)$   | radiative forcing amount                       |
| $T(t)$   | the temperature change                         |
| $t$      | year                                           |
| $k$      | the thermal diffusion coefficient of the ocean |
| $a$      | the rate of sea level rise                     |
| $\alpha$ | the population growth rate                     |
| $M$      | the amount of economic assistance              |

## 4. Model

### 4.1. Model I

#### 4.1.1 Analysis of the Problem

In this section, we focus on the issue of trends in EDP' population. However, population changes are affected by many factors. It is difficult to predict population directly. We turn the question to predicting the trend of sea level rise, which will cause some areas to be flooded, and the population change in the flooded areas is the answer.

Ocean thermal expansion, melting glaciers and so on are the cause of rising sea levels. One of the most reason is global warming. And the global greenhouse effect is a result of the excessive emission of CO<sub>2</sub>. Therefore, the prediction model of sea level change caused by the greenhouse effect is proposed considering to predict population.

#### 4.1.2 Model Design

We will present the mathematical relationships between CO<sub>2</sub> concentrations, atmospheric temperature, and sea level. Based on the change of CO<sub>2</sub> concentrations in the atmosphere in recent years, the change of atmospheric temperature is estimated and the trend of sea level change is predicted.

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### I. Prediction of CO<sub>2</sub> concentrations in the atmosphere

We collect the data of CO<sub>2</sub> concentrations in the atmosphere from 1948 to 2008.

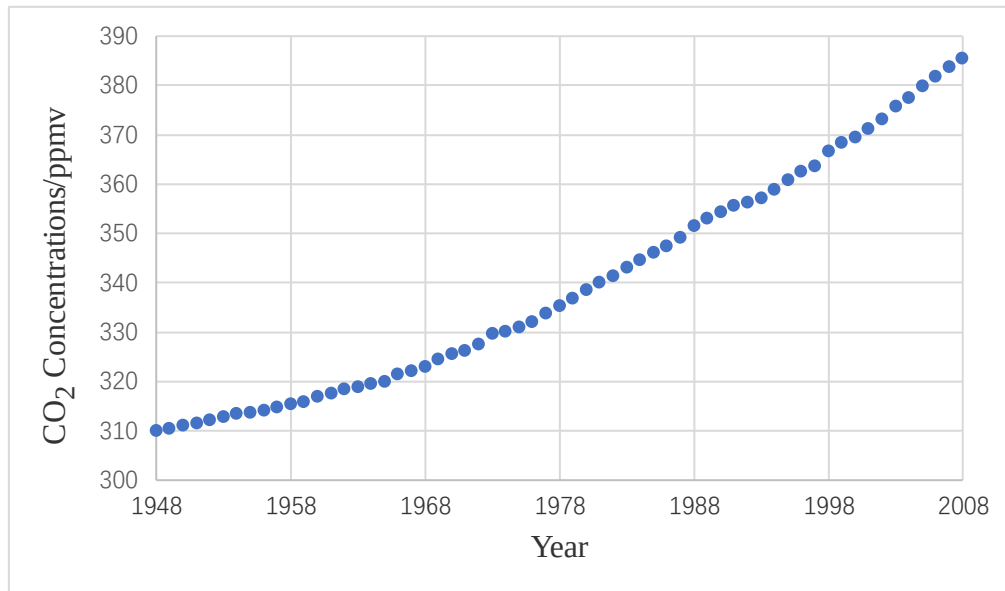


**Figure 1.** CO<sub>2</sub> concentrations data in the atmosphere (1948-2008)

$C$  : CO<sub>2</sub> concentrations/ppmv,  $t$  : year.

Then we make an analysis of fitting equation between  $C$  and  $t$ .

$$\sum_{i=1}^j a_i \frac{d^i Q}{dt^i} = f(Q, t),$$

$$Q = \kappa(c - c_0)\varphi^{-1},$$

$$\varphi = 1 - \exp(-\varepsilon(t - t_0))$$

We introduce the release function  $Q$  and equilibrium coefficient  $\kappa$  to simplify the equation and  $\varepsilon$  is the attenuation coefficient.

$t_0$  : the starting year,  $c_0$  : the starting CO<sub>2</sub> concentrations (1948, 310ppmv)

We take  $a_i$  as the undetermined constant and  $j$  is 2.

$f(Q, t)$  is a polynomial or periodic function of  $Q$  and  $t$ .

Based on the data in figure 1, we consider first-order Taylor expansion.

$$\varphi = \varepsilon(t - t_0), \varepsilon(t - t_0) \ll 1$$

Let  $\kappa = \varepsilon$ ,

$$Q = \varepsilon(c - c_0)\varphi^{-1} = (c - c_0)(t - t_0)^{-1}$$

Then we can obtain a simple equation among the many relations of the trend distribution between  $Q$  and  $t$ .

$$\frac{d^2 Q}{dt^2} + \sigma_1 Q + \sigma_2 = 0, t > t_0$$

Use the undetermined coefficient method.

$$\sigma_1 = 1.00 \times 10^{-4}, \sigma_2 = -1.34 \times 10^{-4}$$

By solving the above equation, the solution can be obtained.

$$Q = 1.34(1 - \cos(0.01(t - 1948) + 0.9))$$

$$t > 1948$$

Tendency equation about the concentration data of CO<sub>2</sub> between 1948-2008 is as follows:

$$C(t) = 1.34(t - 1948) \times (1 - \cos(0.01(t - 1948) + 0.9)) + 310$$

$$t \geq 1948$$

We can use the equation to calculate the concentration data of CO<sub>2</sub> in the atmosphere between 1948-2008. Compare these data with fact data.

It can be seen that the data obtained from the tendency equation of CO<sub>2</sub> concentration data are basically consistent with the fact data.

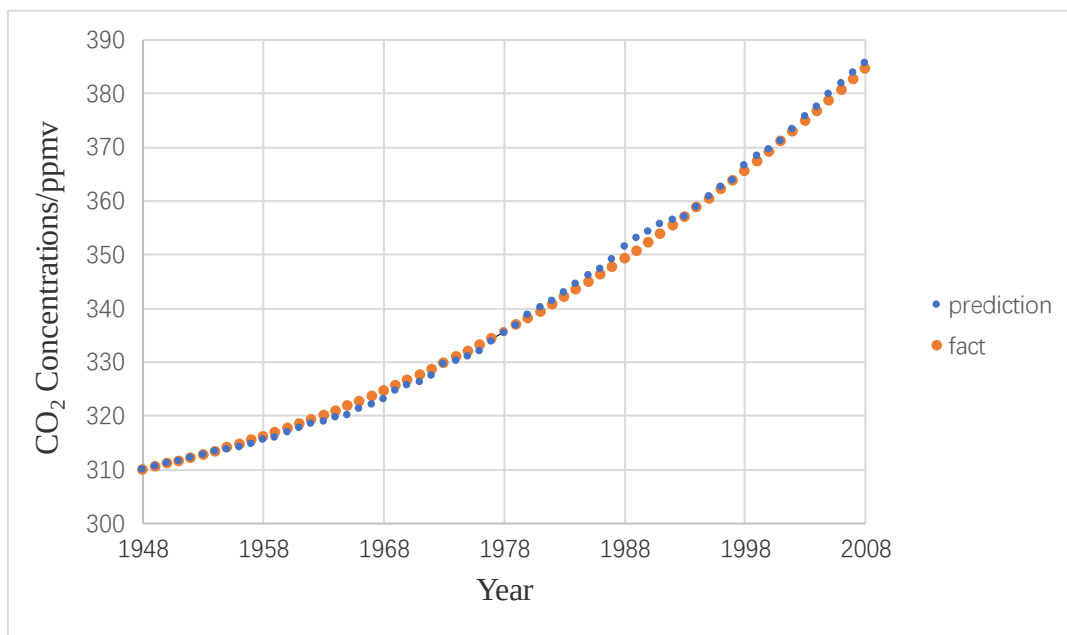


**Figure 2.** CO<sub>2</sub> concentrations contrast

Therefore, we can predict the CO<sub>2</sub> concentrations from 2020 to 2050.

**Table 1.** CO<sub>2</sub> concentration prediction from 2020 to 2050

| Year            | 2020     | 2025     | 2030     | 2035     | 2040     |
|-----------------|----------|----------|----------|----------|----------|
| Predicted value | 411.23   | 423.3991 | 436.2137 | 449.6499 | 463.6848 |
| Year            | 2045     | 2050     | 2055     | 2060     | 2065     |
| Predicted value | 478.2928 | 493.4450 | 509.1096 | 525.2520 | 541.8347 |

## II. Prediction of global temperatures

The radiative forcing amount under the action of greenhouse effect can be written as a function of carbon dioxide emission concentration:

$$F(t) = a_0 + b \ln[C(t)/270.0]$$

$a_0$  and  $b$  can be adjusted according to the carbon dioxide emission concentration and the radiation forcing amount. Based on the existing analysis and estimation, it is appropriate to take  $a_0 = 1.81 \text{ W/m}^2$  and  $b = 2.95 \text{ W/m}^2$ .

Consider the temperature change caused by the increase of CO<sub>2</sub> emission as a function:

$$T(t) = \beta t \ln [\gamma t C(t)/270.0] - 0.5, \beta = 0.00593, \gamma = 0.0114$$

According to scientists' estimates, CO<sub>2</sub> emissions are  $270 \times 10^{-6}$  before the industrial revolution, and the temperature was about 0.5°C lower than around 1980. In order to calculate the sea level change and compare the temperature rise. We regard the temperature in 1980 as 0.

According to the above formula, we calculate the representative  $F(t)$  and  $T(t)$ .

**Table 2.** Radiative forcing amount and global temperature rising

| 2020   |        | 2030   |        | 2040   |        | 2050   |        |
|--------|--------|--------|--------|--------|--------|--------|--------|
| $F(t)$ | $T(t)$ | $F(t)$ | $T(t)$ | $F(t)$ | $T(t)$ | $F(t)$ | $T(t)$ |
| 3.05   | 0.47   | 3.23   | 0.80   | 3.41   | 1.15   | 3.59   | 1.51   |

Note: the unit of  $F$  is  $\text{Wm}^{-2}$ , and the unit of  $T$  is °C.

#### 4.1.3 Model Solution

##### I. Prediction of global sea level

Global warming will cause the thermal expansion of water bodies and the melting of glaciers, leading to global sea level rise. Among them, the thermal expansion of water body is a long-term influence on the entire ocean, which have far greater impact than the melting of glaciers. Therefore, the thermal expansion of water is regarded as the main factor affecting the rise of global sea level.

The sea level prediction equation proposed by Wigeley, well relates temperature change, greenhouse effect intensity and ocean heat diffusion.

$$Z(t) = [4.13 + 2.65F(t)] T(t) k^{0.221}$$

$Z(t)$  is the magnitude of sea level rise or fall in a certain period of time (cm);

$k$  is the thermal diffusion coefficient of the ocean, with values ranging from 0.5 to 3.

Here, we take  $k$  as 0.6, 1.2, 2.0 and 3.0. We plug in the corresponding numerical to calculate the sea level change.

**Table 3.** Global sea level rise

| $k(\text{cm}^2 \cdot \text{s}^{-1})$ | 2020 | 2030  | 2040  | 2050  | 2080  | 2120  |
|--------------------------------------|------|-------|-------|-------|-------|-------|
| 0.6                                  | 5.18 | 9.08  | 13.50 | 18.44 | 31.59 | 66.67 |
| 1.2                                  | 6.04 | 10.59 | 15.74 | 21.50 | 36.82 | 77.71 |
| 2.0                                  | 6.76 | 11.85 | 17.62 | 24.07 | 41.22 | 87.00 |
| 3.0                                  | 7.39 | 12.96 | 19.27 | 26.32 | 45.08 | 95.15 |

According to the table, compared with 1980, we can know that sea level will rise about 5.18~7.39cm around 2020, rise 18.44~26.32cm around 2050, rise 31.59~45.08cm around 2080 and 66.67~95.15cm around 2120.

##### II. Prediction of regional sea level

In fact, sea level rise is not uniform across the globe but regional variations. Therefore, according to geographical location and characteristics of sea-level rise. We divide the global sea

area into 9 sea areas as shown in the figure below, to predict the sea-level change trend of each sea area. Zone 1: east coast of North America, zone 2: South America, zone 3: central Pacific, zone 4: east Asia, zone 5: north American coast, zone 6: Australia, zone 7: Indian Ocean, zone 8: west coast of Europe and Africa, zone 9: Scandinavian peninsula.

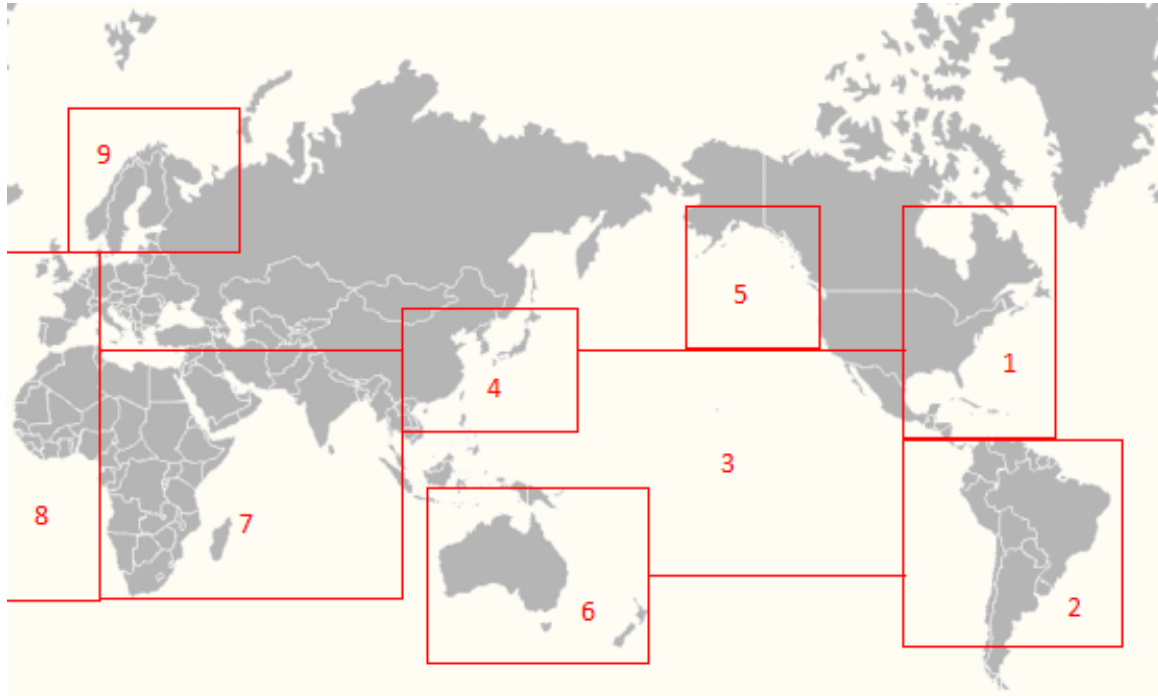


**Figure 3.** 9 regions in global sea

We calculate and analyze 449 tidal stations distributed in 9 regions, get the result that average rate of global sea level rise is 1.41mm/a. The rate of sea level rise in each region is shown below:

**Table 4.** The rate of sea level rise in each region

| Code | Region                          | Number of tidal stations | $a(\text{mm/a})$ | $a'(\text{mm/a})$ |
|------|---------------------------------|--------------------------|------------------|-------------------|
| 1    | east coast of North America     | 82                       | 2.63             | 1.22              |
| 2    | South America                   | 39                       | 1.51             | 0.10              |
| 3    | central Pacific                 | 47                       | 1.38             | -0.03             |
| 4    | east Asia                       | 109                      | 1.05             | -0.36             |
| 5    | north American                  | 23                       | -0.55            | -1.96             |
| 6    | Australia                       | 10                       | 1.05             | -0.36             |
| 7    | Indian Ocean                    | 13                       | 1.25             | -0.16             |
| 8    | west coast of Europe and Africa | 56                       | 1.17             | -0.24             |
| 9    | Scandinavian peninsula          | 54                       | -2.49            | -3.90             |

The prediction model of future sea level rise is put forward from two aspects: the ocean thermal expansion and the trend of sea level rise in each region:

$$Z(t) = Z_1(t) + \zeta(t) = Z_1(t) + a't$$

$Z_1(t)$  is the value of global sea level rise,  $\zeta(t)$  is the value of sea level rise in each sea area, and  $a'$  is the different value of sea level rise rate in each sea area and global sea level rise rate of 1.41mm/a.

We plug in the corresponding numerical to calculate the rate of sea level rise in future:

**Table 5.** Prediction of the rate of sea level rise in each region

| Code | 2020         | 2030         | 2040        | 2050        | 2080        | 2120         |
|------|--------------|--------------|-------------|-------------|-------------|--------------|
| 1    | 10.06~12.27  | 15.18~19.06  | 20.82~26.59 | 26.99~34.86 | 43.79~57.28 | 83.75~112.23 |
| 2    | 5.58~7.79    | 9.58~13.4    | 14.10~19.87 | 19.15~27.02 | 32.59~46.08 | 68.07~96.55  |
| 3    | 5.06~7.27    | 8.93~12.81   | 13.32~19.09 | 18.23~26.11 | 31.29~44.78 | 66.25~94.73  |
| 4    | 3.74~5.95    | 7.28~11.16   | 11.34~17.11 | 15.93~23.80 | 27.98~41.48 | 61.63~90.11  |
| 5    | -2.66~-0.45  | -0.72~3.16   | 1.74~7.51   | 4.73~12.60  | 11.99~25.48 | 39.23~67.71  |
| 6    | 3.74~5.95    | 7.28~11.16   | 11.34~17.11 | 15.93~23.80 | 27.98~41.48 | 61.63~90.11  |
| 7    | 4.54~6.75    | 8.28~12.16   | 12.54~18.31 | 17.33~25.20 | 29.99~43.48 | 64.43~92.91  |
| 8    | 4.22~6.43    | 7.88~11.76   | 12.06~17.83 | 16.76~24.64 | 29.18~42.68 | 63.31~91.79  |
| 9    | -10.42~-8.21 | -10.42~-6.54 | -9.90~-4.13 | -8.85~-0.98 | -7.41~6.08  | 12.07~40.55  |

Due to the change of carbon dioxide and other greenhouse gas emissions, as well as the melting of glaciers, the rise and fall of the crust and other uncertain factors. This estimate carries a degree of uncertainty.

### III. Prediction of the number of EDPs

On the basis of the prediction of sea level rise in the next 100 years, we find the countries that average elevation is lower than 1 meter. These countries are at a high risk of being submerged. Most are island countries in the central Pacific Ocean, including Palau, Mikasa, Nauru, Tuvalu, Samoa, Fiji, tonga, Kiribati and Marshall Islands. The Maldives in the Indian Ocean and the Netherlands on the west coast of Europe.



**Figure 4.** Low altitude country

The following is the amount of the sea level rise in the next 100 years, in central Pacific, Indian Ocean, west coast of Europe and Africa:

**Table 6.** Sea level rise in the next years

| Code | Region                          | 2050        | 2080        | 2120        |
|------|---------------------------------|-------------|-------------|-------------|
| 3    | central Pacific                 | 13.70~18.84 | 26.23~37.51 | 61.19~87.46 |
| 7    | Indian Ocean                    | 12.79~18.45 | 25.45~36.73 | 59.89~86.16 |
| 8    | west coast of Europe and Africa | 12.54~18.21 | 24.96~36.25 | 59.89~86.16 |

When sea level rises above a country's average elevation, the country will be flooded and uninhabitable. EDPs must migrate to survive. Therefore, by comparing the height of sea level rise with the average elevation of a country, we can predict if a country will be flooded.

The following table shows the average altitude of low-altitude countries:

**Table 7.** The average altitude of countries

| Country               | Palau    | Microtia | Nauru    | Tuvalu      | Samoa | Fiji     |
|-----------------------|----------|----------|----------|-------------|-------|----------|
| Average altitude (cm) | 77       | 96       | 57       | 150         | 89    | 200      |
| Country               | Kiribati | Marshall | Maldives | Netherlands | Tanga | Kiribati |
| Average altitude (cm) | 200      | 200      | 120      | 200         | 88    | 200      |

In comparison, it is estimated that Palau, Nauru, Samoa and tanga will be submerged in the next 30 years; Tuvalu, micropsia and Maldives will be submerged within the next 30 to 60 years. Fiji, Kiribati, Marshall, the Netherlands, and Bangladesh will be submerged within the next 60 to 100 years.

The migration of EDPs is a national migration. Therefore, the population of the country can be counted as the number of EDPs.

population growth model:

$$N(t') = n \times (1 + \alpha)^{t'-2020}$$

$t'$  is the year when the country is submerged,  $n$  is the population in 2020, and  $\alpha$  is the population growth rate. We plug in the data and calculate the population of each country at the time of flooding. Then we regard the population as the number of EDPs.

**Table 8.** The population in 2020

| Country     | Population in 2020 | Increase rate | Year of being flooded | Population of being flooded |
|-------------|--------------------|---------------|-----------------------|-----------------------------|
| Netherlands | 17084459           | 0.28%         | 2120                  | 22596115                    |
| Palau       | 21964              | 1.08%         | 2050                  | 30316                       |
| Tanga       | 109008             | 0.91%         | 2050                  | 143049                      |
| Fiji        | 912241             | 0.74%         | 2120                  | 1906797                     |
| Samoa       | 197695             | 0.64%         | 2050                  | 239394                      |
| Microtia    | 106227             | 0.65%         | 2080                  | 156698                      |
| Maldives    | 444259             | 1.82%         | 2080                  | 1311058                     |
| Nauru       | 11312              | 0.00%         | 2050                  | 11312                       |
| Tuvalu      | 11287              | 0.85%         | 2080                  | 18756                       |
| Kiribati    | 118414             | 1.73%         | 2120                  | 658124                      |
| Marshall    | 53167              | 0.08%         | 2120                  | 57594                       |
| Bangladesh  | 166368149          | 1.03%         | 2120                  | 463559498                   |

Bangladesh is so vast that most of the land is landlocked and only a small part of the land is near the sea. Therefore, it is impossible for the whole country to be submerged. Only a quarter of the population is expected to move when some of the land is submerged. And the migration of some large countries is a long process, over a long period of time, so the number of EDPs is only a fraction of the total. Summing up the figures in the table above, we can get the conclusion that

there are 490,000 EDPs in the next 30 years, 9,370,000 EDPs in the next 60 years and 140,000,000 EDPs in the next 100 years.

The predicted number of climate refugees is low because low-altitude countries that will be flooded are not fully taken into account.

## 4.2. Model II

### 4.2.1 Analysis of the Problem

Due to sea level rise, many areas are about to be flooded or are at potential risk of being flooded. People in these areas need to plan their migration strategies in advance so that they can respond when danger strikes. In migration strategies, the risk of loss of the unique culture, language, and life of EDPs also needs to be taken into account. So we analyze the risk of cultural loss in order to pick the right place to move. We divide the risk of cultural loss into three aspects: the cultural value of environmental displaced country, the influence of recipient country and the international protection.

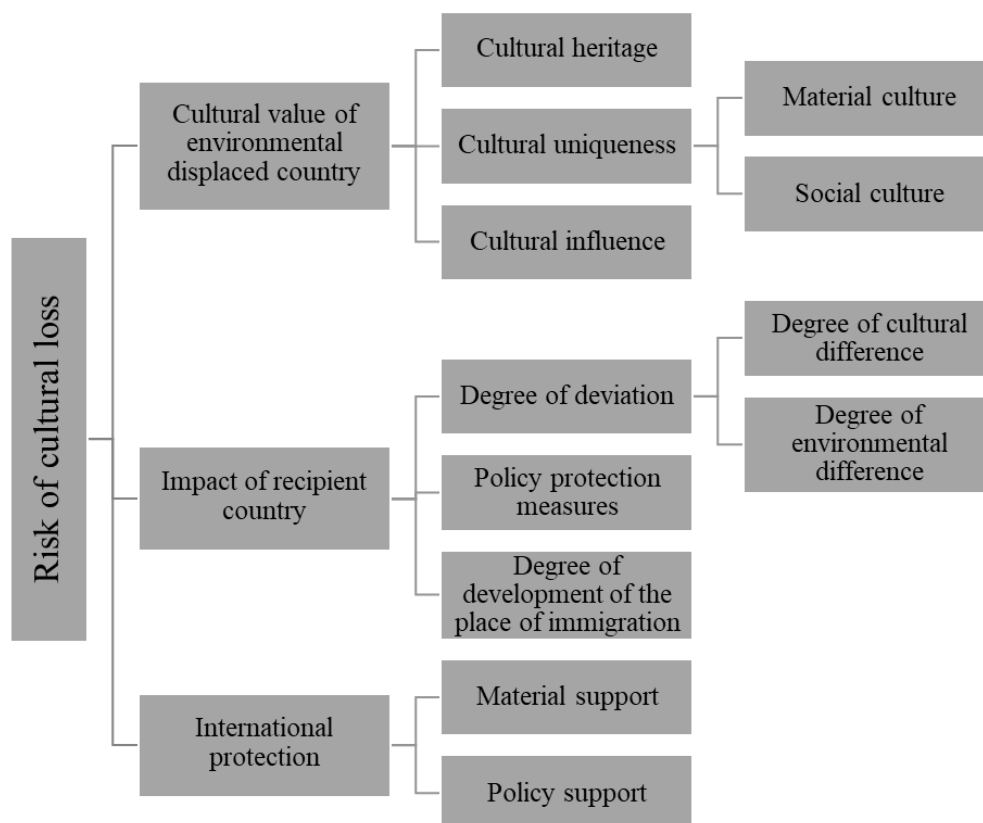


**Figure 5.** Risk factors of cultural loss

The cultural value of environmental displaced country includes cultural inheritance, cultural uniqueness (material culture, social culture) and cultural influence. The influence of recipient country includes the degree of difference (cultural difference, environmental difference), policy protection measures and the development degree of recipient country. International protection includes material and policy support. Then we use Analytic Hierarchy Process to analyze each factor and get the weight. Then, we use the Fuzzy Comprehensive Evaluation Method to determine the average evaluation value of the influence of recipient country. We use the scoring system to quantify the factors that affect recipient country, so that the units of each factor are consistent. We multiply the weight obtained by Analytic Hierarchy Process and the average evaluation value to obtain the weighted average evaluation value, and finally form the comprehensive evaluation value of each resettlement, that is, the evaluation model of the best resettlement location can be obtained.

## 4.2.2 Model Design

The main factors we consider for the risk of cultural loss are as follows:

**Table 9.** Rank priority of factors

| factors                                         | symbol | Rank priority |
|-------------------------------------------------|--------|---------------|
| Local material and cultural uniqueness          | MC     | 1             |
| Local social and cultural uniqueness            | SC     | 1             |
| Degree of cultural difference                   | CD     | 2             |
| Degree of environmental difference              | ED     | 2             |
| Local cultural heritage                         | CH     | 3             |
| International policy support                    | IP     | 4             |
| Policy protection measures of recipient country | PP     | 4             |
| International material support                  | IM     | 5             |
| Local cultural influence                        | CI     | 6             |
| Degree of development of recipient country      | DD     | 7             |

Using analytic hierarchy process, we construct a judgment matrix for the priority of each factor of cultural loss risk, and determine the structure of each factor. The following formula can be obtained:

Take two factors  $a_i$  and  $a_j$  at a time to compare their influence on the risk of cultural loss, and  $a_{ij}$  is used to represent them, the results of all comparisons are expressed in paired comparison matrices.

$$A = (a_{ij}), a_{ij} > 0, a_{ij} = \frac{1}{a_{ji}}$$

A is a positive reciprocal matrix.

For example, in the risk of cultural loss:

$$a_{12} = 1/2 = \frac{C_1(\text{Local material and cultural uniqueness})}{C_2(\text{The degree of cultural difference between the place of immigration and the local area})}$$

Expression: the importance of C1 to the risk of cultural loss is 1, and the importance of C2 to the risk of cultural loss is 2.

The pairwise comparison matrix is as follows:

$$A = \begin{pmatrix} 1 & 1 & 2 & 2 & 3 & 4 & 4 & 5 & 6 & 7 \\ 1 & 1 & 2 & 2 & 3 & 4 & 4 & 5 & 6 & 7 \\ 1/2 & 1/2 & 1 & 1 & 3/2 & 2 & 2 & 5/2 & 3 & 7/2 \\ 1/2 & 1/2 & 1 & 1 & 3/2 & 2 & 2 & 5/2 & 3 & 7/2 \\ 1/3 & 1/3 & 2/3 & 2/3 & 1 & 4/3 & 4/3 & 5/3 & 2 & 7/3 \\ 1/4 & 1/4 & 1/2 & 1/2 & 3/4 & 1 & 1 & 5/4 & 3/2 & 7/4 \\ 1/4 & 1/4 & 1/2 & 1/2 & 3/4 & 1 & 1 & 5/4 & 3/2 & 7/4 \\ 1/5 & 1/5 & 2/5 & 2/5 & 3/5 & 4/5 & 4/5 & 1 & 6/5 & 7/5 \\ 1/6 & 1/6 & 1/3 & 1/3 & 1/2 & 2/3 & 2/3 & 5/6 & 1 & 7/6 \\ 1/7 & 1/7 & 2/7 & 2/7 & 3/7 & 4/7 & 4/7 & 5/7 & 6/7 & 1 \end{pmatrix}$$

**Table 10.** The weight of each factor of cultural loss risk

| Factor | MC     | SC     | CD     | ED     | CH     |
|--------|--------|--------|--------|--------|--------|
| Weight | 0.2303 | 0.2303 | 0.1151 | 0.1151 | 0.0768 |
| Factor | IP     | PP     | IM     | CI     | DD     |
| Weight | 0.0576 | 0.0576 | 0.0461 | 0.0384 | 0.0329 |

#### 4.2.3 Model Testing

Consistency test of Analytic Hierarchy Process:

Calculate the maximum eigenvalue of A above:  $\lambda_{max}(A) = 10$

Consistency Indicators:  $CI = \frac{\lambda_{max}(A) - 6}{6 - 1} = 0$

Find out:  $RI = 1.12$   $CR = \frac{CI}{RI} = 0 < 0.1$

This shows that A isn't a consistency matrix. However, A has satisfactory consistency and the degree of inconsistency of A is acceptable. The results are credible and accept the original model.

**Figure 6.** Maldives migration route

Due to sea level rise, many areas are about to be flooded or are at potential risk of being flooded. People in these areas need to plan their migration strategies in advance so that they can respond when danger strikes. In migration strategies, the risk of loss of the unique culture, language, and life of EDPs also needs to be taken into account. So, we analyze the risk of cultural loss in order to pick the right place to move. We divide the risk of cultural loss into three aspects: the cultural value of environmental displaced country, the influence of recipient country and the international protection. The cultural value of environmental displaced country includes cultural inheritance, cultural uniqueness (material culture, social culture) and cultural influence. The influence of recipient country includes the degree of difference (cultural difference, environmental difference), policy protection measures and the development degree of recipient country. International protection includes material and policy support. Then we use Analytic Hierarchy Process to analyze each factor and get the weight.

We take Maldives as an example. After quantifying 8 factors, we use principal component analysis to analyze 8 indicators of 3 countries to migrate, calculate the principal component, construct the comprehensive evaluation function F, and then select the best country to relocate after the weighted sum of each principal component is obtained.

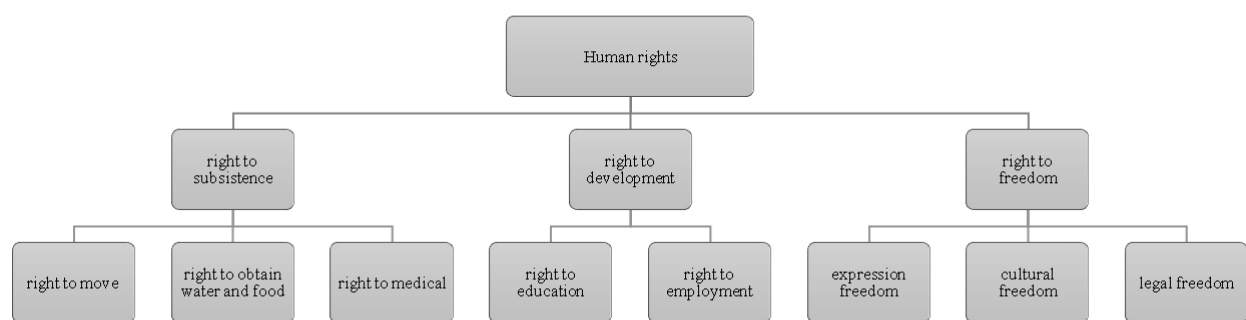
**Table 11.** Comprehensive scores of each country

| Country   | Evaluation  | Ranking |
|-----------|-------------|---------|
| India     | 2.199811931 | 1       |
| Sri Lanka | 1.537247725 | 2       |
| Australia | 1.296041131 | 3       |

### 4.3. Model III

#### 4.3.1 Human Rights

EDPs are still developing persons, so their human rights should be guaranteed. The following is a few basic human rights that must be guaranteed:

**Figure 7.** Human rights

The right to subsistence. This right is the most basic and important human right that must be fully guaranteed. EDPs' right to subsistence is seriously threatened because of nowhere to live. So, the international community should provide appropriate assistance to ensure that EDPs' right to life is properly protected. To protect the right to life, we could proceed from the following aspects:

(1) Right to move. EDPs must in search of a new land to live by migrating. International organizations can adopt policies to help climate refugees find new homes. Countries take the initiative to accept and resettle EDPs out of moral concern.

(2) Right to obtain water and food. Water and food are necessary for human existence. Without it, life cannot continue. Therefore, when EDPs migrate to new countries, this right also must be fully guaranteed. The international can give the grain allowance to the recipient country. The recipient country could increase productivity, improve the grain production to meet the newly added needs.

(3) Right to medical. People will be sick and even death without timely treatment. EDPs are entitled to enjoy a sound medical system and receive medical treatment. The international can provide subsidies for medical materials. The recipient country should actively develop the construction of local medical facilities, and improve the medical environment. For example, train more medical personnel, build hospitals, increase the number of ambulances, to meet the added medical needs.

The right to development. A man only can survive is totally not enough. The value of a man lies in the realization of his thoughts and the development of himself. Therefore, on the basis of survival, the right to individual development is particularly important. To protect this right, we should focus on the following aspects:

(1) Right to education. Education is an effective way to acquire knowledge that will help

you to improve and develop yourself. If the school-age children of EDPs cannot receive education, their cultural literacy and ideological quality will decline, leading to productivity, economic backwardness and social regression.

(2) Right to employment. People need to work, get economic reward by hard work, to maintain their livelihood and realize their value. If EDPs are unable to find jobs in recipient country, they will have no source of economic resources. They may become homeless groups.

The right to freedom, not absolute freedom but relative freedom under the restriction of management. The right includes the following aspects:

(1) Expression freedom, is a basic human right. People have the political right to express their opinions and ideas as they wish, without being subject to government censorship or restriction. EDPs should also have this right to express freely, to express their ideas and raise their suggestions and requirement.

(2) Cultural freedom. When the EDPs integrate into the recipient country, they will receive the new local cultural edification and learn the local language and customs, but they can still retain their own original language and customs. integrate them without being assimilated. Cultures merge but do not assimilate.

(3) Legal freedom. EDPs will be governed by the laws of the recipient country, but they can negotiate certain aspects of the laws, retain some of the original laws and regulations, and then combine into new regulations for EDPs.

#### 4.3.2 Culture

Culture is the product of human society, the carrier of human spiritual activities, and the material and spiritual wealth of human social activities. Culture is a country's soft power, with a strong influence, permeating people's life, affecting people's thought and behavior. The protection of culture can be analyzed from three aspects: cultural uniqueness, cultural inheritance and cultural influence.

Cultural uniqueness. The uniqueness of culture is mainly reflected in the daily clothing, food, shelter and transportation of human beings. Clothing is known as a history book, which can reflect the local conditions and customs of a country. The dress of south Pacific island country has tropical amorous feelings. Its color is gorgeous and lively, material is natural and simple, the pattern is mostly stripe; Food. Island country possess vast sea area and rich sea resources. So, they mostly eat fish, crabs and other seafood, and have their unique processing and cooking techniques. Architecture. Pacific island countries have a hot, sunny climate, so the buildings on the island are very different from the usual concrete and steel buildings. Most of them are low houses, built with local raw materials, such as thatch, coconut tree trunks, etc. Transportation. Because Pacific island countries are mostly small, so the transportation is relatively primitive and simple.

Cultural inheritance. Cultural inheritance refers to the transmission of culture, between people or two generations. The inheritance of folk customs and religions is reflected in People's Daily life. The legal system is inherited by the constantly revised and improved constitution. Intangible cultural heritage is the essence of traditional cultural inheritance, which needs to be well protected and strengthened.

Cultural influence. A country's cultural influence is not only for its native people but also can be exported to affect the world. Culture can be presented to the world in the form of literature such as books and films. It can also be reflected in policy democracy and spread in the form of ideas. The influence of culture is invisible and powerful, and the influence on people is permeable.

#### 4.3.3 Multi-objective Programming

The problem of this section is that in the case of an increasing number of EDPs, national, regional and international efforts should have a positive attitude to understand the current situation and make policies for better sustainable development. And we provide the basis for policy making below.

We need to address not only the resettlement of people who have already left their homeland, but also the resettlement of those who will become EDPs in the future. Where will the EDPs go? Does the migration consume large resources? Are the recipient countries suitable for EDPs to live in?

Considering that the problems cover many aspects, we extract three objectives and apply multi-objective programming method, so as to develop the best solution of the recipient countries selection, resources consumption during migration and livability after migration.

First of all, the recipient countries cannot be far away, so the distance between the two country is one of the objectives we should consider. Secondly, the environmentally displaced countries are mainly concentrated on tropical islands in the Pacific Ocean, so the way of migration and the cost of money are one of the objectives. Then, after migration, economic risks, political instability and so on are negative, so the livability also should be considered. The objective function is as follows:

$$\max \sum_{j=1}^m \sum_{i=1}^n x_{ij} s_j \quad \min \sum_{j=1}^m \sum_{i=1}^n x_{ij} d_{ij} \quad \min \sum_{j=1}^m \sum_{i=1}^n x_{ij} r_{ij}$$

$x_{ij}$ : the number of EDPs from the displaced country  $i$  to the recipient country  $j$ ;

$s_j$ : the livability of the recipient country;

$r_{ij}$ : the economic losses from the displaced country  $i$  to the recipient country  $j$ ;

$d_{ij}$ : the length of the route from the displaced country  $i$  to the recipient country  $j$ .

Constraints:

$$\sum_{i=1}^n x_{ij} \leq M_j (j = 1, 2, \dots, n)$$

$M_j$ : the maximum number of EDPs that the displaced country can bear

Multi-objective programming considers the above problems comprehensively and provides a theoretical basis for policy formulation.

#### 4.3.4 EDPs Protection Policy

1. Recipient country should guarantee the basic human rights of refugees, such as health care, education and employment.

As EDPs continue to enter recipient countries, their health care, education and employment will come under greater pressure. Recipient country should ensure the basic living needs of EDPs, such as helping them build infrastructure such as hospitals and schools. At the same time, recipient countries can expand their own industries to absorb more workers and promote local economic development while solving the problem of EDPs employment.

2. All countries in the world undertake the responsibility of receiving EDPs in a common but differentiated way.

In terms of the policy of accepting EDPs, it is impossible to receive EDPs with the same standard due to the difference in economic strength between developing countries and developed countries. Countries will do their best to cooperate internationally to build and improve refugee response capacity.

3. Implementing relevant measures and providing assistance at the national, regional and international levels.

Our policies include international assistance, national responsibility and regional coordination. Internationally, the United Nations has provided protection for EDPs through the formulation of UN Framework Convention on Climate Change and other conventions. In terms of the country, environmental displaced country should make relevant plans in advance and sign an agreement with recipient country before moving. At the regional level, recipient country is required to provide land for the resettlement of EDPs and make appropriate plans in advance in the region to prepare for the reception and prevent regional conflicts.

4. Recipient country shall protect the religious belief, language and other cultures of environmental displaced country.

After citizens of environmental displaced country enter recipient country, recipient country should respect the religious belief and language of environmental displaced country and ensure the cultural freedom and equality of citizens of environmental displaced country. At the same time, recipient country should actively introduce policies to guarantee the cultural integration of environmental displaced country.

5. EDPs receive unified management and enjoy certain political autonomy.

Autonomous regions can be established in the places where EDPs live, and citizens enjoy certain political autonomy. It is suggested that the government of the autonomous region should send some representatives to participate in the political decision-making of the country, so as to cultivate citizens' sense of national responsibility and sense of identity.

6. To retain maritime jurisdiction over the vanished islands.

The biggest victims of sea-level rise are small islands, and in the absence of territory, the UN could propose a scheme to recognize small islands' maritime jurisdiction, reserving jurisdiction over the island's sea area.

#### 4.3.5 Policy Potential Impact Assessment

After the policy is formulated, it will have a series of impacts on the recipient country, such as the change of attitude towards the environment, the adjustment of administrative division, the change of cultural, the change of international relations, the change of economic development, the change of ideology and so on. In terms of environmental attitudes, considering that some countries have insufficient environmental protection, the United Nations may increase the quota of accepting EDPs in these countries to urge them to implement energy conservation and emission reduction. At the same time, recipient countries will pay more attention to the protection of the environment due to the environmental deterioration caused by the huge population in the place of migration. In terms of administrative divisions, recipient countries will allocate a region as a settlement site for environmental displaced countries, establish an autonomous region or an independent country, and make some adjustments to the administrative divisions. In order to protect the legitimate rights and interests of the autonomous region, the autonomous region will elect representatives to participate in the decision-making of the central government. In terms of cultural diversity, after EDPs move in, their unique culture will collide with the local culture and constantly integrate into the local culture, thus leading to the change of local cultural diversity. After EDPs enters recipient country, the international visibility and national strength of recipient country will be improved to some extent, and the relationship among recipient country and other countries will have subtle changes. Since most of EDPs are located in small islands, we don't consider the geopolitical impact of the merger of major powers as a factor. The economic development mode of recipient country is different from environmental displaced country. Different fields can complement each other. The same field will produce assistance or competition. Due to the differences in religion, culture, language, politics and other aspects between the two places, EDPs may have ideological conflicts after they move into recipient country. After the

implementation of the policy, we need to investigate the actual situation, then analysis and formulation.

After the formulation of EDPs policy, we use the goal-oriented assessment model to measure the goal and evaluate the degree. Objective measurement refers to whether the policy results are consistent with the predetermined goals, while degree evaluation is an analysis of the extent to which the policy projects produce the expected results. Objective oriented assessment takes the objective as the logical starting point, and its assessment route is mainly composed of three parts: first, find out the objectives of policy projects, sort out their actual meanings and convert them into measurable standards; second, measure the actual values of various objectives; third, assess the realization degree of the objectives.

We analyze the six major impact areas, including the change of environmental attitudes, the adjustment of administrative divisions, the change of cultural diversity, the change of international relations, the change of economic development, and the ideological conflict. First of all, we define a quantifiable standard in each policy, then measure the actual value of the standard, and finally analyze the potential impact.

For example:

1. In terms of economic development and change, we take the financial input-output ratio as the quantitative standard. When the climate refugees migrate, the government will first invest in the infrastructure of the moving area, which will consume part of the tax revenue. After investment, local government tax will be increased every year.

Input output ratio formula:

$$R = K / IN = 1 / N$$

K is the total investment. IN is the sum of the added value of each year in the project life cycle.  $N = IN / K$ . The greater the N value is, the better the project economy is.

2. In terms of attitude change towards the environment, we take the per capita carbon emissions of countries as the standard, and the per capita carbon emissions proposed by countries in the United Nations framework convention on climate change as the target.

Carbon emission calculation formula:

CO<sub>2</sub> emission (kg) of household electricity = power consumption × 0.785

CO<sub>2</sub> emission (kg) of driving = fuel consumption liters × 0.785

CO<sub>2</sub> emissions from short-haul air travel (within 200 km) = mileage × 0.275

CO<sub>2</sub> emissions from intermediate air travel (200km to 1000km) = 55 + 0.105 × (mileage - 200)

CO<sub>2</sub> emissions from long-haul air travel (200km to 1000km) = 55 + 0.105 × (mileage - 200);

We use the ratio of carbon emissions per person to the expected carbon emissions to calculate the reduction effect.

Emission reduction effect formula:

$$E = PC/EC$$

**Table 12.** Ranking of carbon emissions per capita in major countries

| Country | Emissions/10 <sup>8</sup> t | Population/10 <sup>6</sup> | Per capita emissions/t | Emission reduction targets |
|---------|-----------------------------|----------------------------|------------------------|----------------------------|
| China   | 128.49                      | 1395.38                    | 9.21                   | Unfinished                 |
| US      | 51.03                       | 333.07                     | 15.32                  | Unfinished                 |
| India   | 24.55                       | 1370.08                    | 1.79                   | Finished                   |
| Russia  | 17.65                       | 146.53                     | 12.04                  | Unfinished                 |
| Japan   | 13.21                       | 125.98                     | 10.49                  | Finished                   |
| Germany | 7.97                        | 80.45                      | 9.91                   | Finished                   |

In the above formula, PC is the per capita carbon emissions, and EC is the expected per capita carbon emissions. The smaller the E value, the better the emission reduction effect.

Taking developing countries and developed countries as the criteria for distinguishing between them, we have selected countries with incomplete emission reduction targets and high per capita emissions respectively to provide necessary economic assistance to countries suffering from environmental problems.

Formula for calculating the economic assistance of countries to the displaced country:

$$M = (E - 1) \times TE \times DC$$

M is the amount of economic assistance, TE is the total carbon emissions, and DC is the country category. Developing countries  $DC=1/2$ , developed countries  $DC=1$ .

#### 4.3.6 The importance of policy implementation

In order to better solve the EDP problem, we put forward effective policies from three aspects: before, during and after migration. Next, we explain the importance of implementing the policies.

Before the migration:

Environmentally displaced countries can get assistance and recipient countries can obtain aid programmes in accordance with the policy.

"All countries in the world undertake the responsibility of receiving EDPs in a common but differentiated way."

The purpose of this policy is to make the world to recognize the urgent international environmental situation. Nature is constantly retaliating against humans, so the world should face up to environmental problems. We first should solve existing problems and then prevent future problems. Furthermore, the policy states that countries around the world need to assume responsibility for receiving EDPs in a differentiated way. Inevitably, countries will argue about the number of EDPs reception. Due to the different national conditions of countries, the different number of EDPs they can bear, and the different degree of damage to the environment they cause, the corresponding responsibilities they undertake are also different. Taking these factors into consideration, the international community should put forward an objective and scientific plan for countries to shoulder the responsibility of EDPs, catch the attention of all countries, reduce conflicts, and reduce the EDPs' losses.

During the migration:

Environmentally displaced countries can greatly reduce the losses caused by migration in accordance with the policy.

"Implementing relevant measures and providing assistance at the national, regional and international levels."

Without the policy, the affected countries are isolated. Migration is a long and resource-consumption process, which will make the economy of the country to be volatile and social instability. The implementation of the policy will accelerate the migration process and minimize the countries' economic, cultural and other losses.

After the migration:

The policy is of great significance for the stability of both environmentally displaced countries and recipient countries and for their future sustainable development.

In the previous question, we establish the goal-oriented assessment model to measure the goal and evaluate the degree. Through measuring and comparing of the metric data before and after implement, we can find that the policy will have an impact on cultural diversity, economic development and the people's attitude towards the environment and so on.

In the second question, we establish risk assessment model for cultural loss, which can directly show the cultural value of the environmentally displaced countries and the cultural losses

caused by the migration. The policy "Recipient country shall protect the religious belief, language and other cultures of environmental displaced country" means that the recipient countries cannot be forced to assimilate the EDPs. Meanwhile, they should protect the unique culture of EDPs, such as language, religion, cultural heritage and so on. It is of great significance to protect the precious culture, promote cultural inheritance, maintain international cultural diversity, and may create new cultural values through cultural fusion.

"Recipient countries should guarantee the basic human rights of refugees, such as health care, education and employment etc." This policy is mainly for social stability. If EDPs don't enjoy basic human rights in the recipient countries, and don't have the necessary rights for daily needs. Then the region where the EDPs live will be a mess, which will even affect the functioning of various industries, such as education and healthcare in the recipient countries. Moreover, if the political problems of EDPs aren't taken seriously, the ideological conflicts may escalate into military conflicts with irreversible effects.

The policy that "EDPs receive unified management and enjoy certain political autonomy." is aimed to maintain the continuity of their relationship with national nationality and reduce the number of stateless persons.

## 5. Evaluating our Model

### 5.1. The Strengths of Model

The change trend of global CO<sub>2</sub> concentrations in model I is easy to calculate, so that global temperature change and sea level rise trend can be calculated, and the number of EDPs can be predicted.

In model I, we divided the global sea area into nine regions, making the calculation of sea level rise more accurate.

Model II considers the risk of possible cultural loss of environmental displaced country from three aspects: environmental displaced country itself, the influence of recipient country, and international protection, which is relatively comprehensive.

The evaluation criteria of the goal-oriented model in model III are relatively objective, and the results of a project can be judged by the completion of project goals. This cautious evaluation method avoids the subjective evaluation of the project.

### 5.2. The Weaknesses of Model

In model I, when a country is predicted to be under water, we consider its overall relocation.

Not taking into account changes in cultural values over time.

When evaluating the potential impact of policies, it is not comprehensive to select representative indicators as quantification.

## 6. Conclusion

After using the goal-oriented model to evaluate the target, we also need to carry out real-time tracking and investigation of the resulting situation in the implementation process, so as to achieve the purpose of dynamic modification of the policy. Because the goal-oriented model only USES preset goals to evaluate, it ignores the evaluation of some unexpected or unexpected policy effects. Here we use the side-effect assessment model to refine the proposed policy, extending the goal-directed model to include side-effects as well. It is characterized by the consideration of side effects while retaining the evaluation of the preset target. The policy side effect is a concept corresponding to the preset target effect, which mainly refers to the effect of the policy outside the target scope, that is, the public policy may produce some other consequences beyond the expected results.

After the improvement of the proposed policy, we used the side-effect assessment model to analyze specifically the changes in cultural diversity in the six main impact areas listed.

In terms of cultural diversity change, EDPs have a low impact on cultural transmission after they enter recipient country, because they need to adapt to the local environment and build a new country. Over time, EDPs will gradually integrate into local society, and their influence will further speed up cultural transmission. In this case, we use the side effect assessment model to evaluate the possible future effects, and propose improvement measures. For example, relevant majors should be set up in colleges and universities in advance to conduct research and analysis on cultural integration. Inherit the navigation and hunting skills of the climate refugees and apply them to their current residence.

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