|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  | | --- | --- | | For office use only | | | T1 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | T2 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | T3 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | T4 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | |  | | --- | | Team Control Number **1912863** | |  | | Problem Chosen **B** | | |  |  | | --- | --- | | For office use only | | | F1 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | F2 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | F3 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | F4 | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | |   **2019 MCM/ICM Summary Sheet** |

While the economic theory usually neglects the impact of economic constructing, the environment is facing its consequence. In this essay, we will discuss the impact of land-used project on the ecosystem and value the real cost of the project considering the project’s influence.

In our first model, we do some preparation work for our modeling. We divide the whole ecosystem into four parts: pedosphere, hydrosphere, atmosphere and the biosphere to research project’s impact on different sections of the environment. Besides, considering the correlated relation between the different spheres, we also discuss their internal relation. For different kinds of projects influences different spheres in different levels, we also classify several common projects and research their impact on different spheres in different level.

In our second model, we construct an evaluation system to estimate the quality of the environment. We construct models to individually evaluate the quality of different spheres, taking their specific characteristics into account. Finally, we combine the index of different spheres and get an evaluation index for the total ecosystem.

In the third model, we first research the impact of the project on the environment. We divide the impact into the constructing impact and the followed-up impact. We qualify the impact according to the area, exploiting degree, technology, the original environment quality and some other factors of the construction. Having individually got the impact on a certain sphere, we also find the connection between the factors and get the final evaluation index for the impact.

Then, we research how the impact influence the economic change in the local. We consider the change of the local production costs, the change of the death rate and the diseases caused by the change of environment. By combining these factors, we get a relatively comprehensive valuation for extra cost of the projects.

Finally, we do the sensitivity analysis and get that our model is stable.

|  |
| --- |
| Evaluation System for the Ecosystem |

Contents

[1. Introduction 3](#_Toc536511503)

[1.1 Background 3](#_Toc536511504)

[1.2 Problem Restatement 3](#_Toc536511505)

[1.3 Literature Review 3](#_Toc536511506)

[2. General Assumptions 3](#_Toc536511507)

[3. Model A: Preparation Model 3](#_Toc536511508)

[3.1 Model overview 3](#_Toc536511509)

[3.2 The Sections of the Ecosystem 4](#_Toc536511510)

[3.3 The Classification of the Land-Use Projects 5](#_Toc536511511)

[4.Model B: Evaluation for Impact 5](#_Toc536511512)

[4.1 Model Overview 5](#_Toc536511513)

[4.2 Variable Table 5](#_Toc536511514)

[4.3 Evaluation for the Water Quality 6](#_Toc536511515)

[4.3.1 Composite Index Analysis Method 6](#_Toc536511516)

[4.3.2 Nemerow Method 7](#_Toc536511517)

[4.3.3 Comprehensive Weight Analysis Method 7](#_Toc536511518)

[4.4 Evaluation for the Air Quality 8](#_Toc536511519)

[4.5 Evaluation for the Soil Quality 8](#_Toc536511520)

[4.5.1 The Physical Factors 8](#_Toc536511521)

[4.5.2 The Chemical Factors 9](#_Toc536511522)

[4.5.3 The Pollutants 10](#_Toc536511523)

[4.6 Evaluation for the Biosphere 10](#_Toc536511524)

[4.6.1 The Simpson Index 10](#_Toc536511525)

[4.6.2 The Shannon Index 10](#_Toc536511526)

[4.7 The Evaluation Index for the Ecosystem 11](#_Toc536511527)

[4.8 Model Conclusion 11](#_Toc536511528)

[5. Model C: The Valuation for the Cost 11](#_Toc536511529)

[5.1 Model Overview 11](#_Toc536511530)

[5.2 Model Assumption 11](#_Toc536511531)

[5.2 Constants and Variables 11](#_Toc536511532)

[5.3 The Total Expression 12](#_Toc536511533)

[5.4 Constructing Impact 12](#_Toc536511534)

[5.5 Impact on Pedosphere 13](#_Toc536511535)

[5.6 Impact on Hydrosphere 14](#_Toc536511536)

[5.7 Impact on Atmosphere 16](#_Toc536511537)

[5.8 Impact on Biosphere 17](#_Toc536511538)

[5.9 The Valuation for the “Extra” 17](#_Toc536511539)

[6. Sensitive Analysis 19](#_Toc536511540)

[7. Strengths and weaknesses 19](#_Toc536511541)

[9. References 20](#_Toc536511542)

1. Introduction

## 1.1 Background

The environment theories often ignore its impact on the biosphere and assume unlimited resources. However, it may have limitations and flaws and can’t adapt to our current environment which is facing problems. As we construct buildings and alter the land use, we limit and remove the ecosystem service more or less. As individually the land-use alters seem inconsequential to the total biosphere, they are impacting the biodiversity and causing environment degradation cumulatively.

## 1.2 Problem Restatement

Most land use projects do not take the impact of the ecosystem services into consideration. Besides, the economic costs to mitigate negative results of the land use changes are also often not included in the plan. In this essay, we will construct mathematical models to solve the problems below.

1. Model the impact of land-use projects to the biosphere, value the costs of dealing with the impact on the biosphere.
2. Give solutions to mitigate the negative affection of the projects and deal with the pollutions. Consider the cost of the solutions and find the best one costing least and get an assessed valuation of the project.

## 1.3 Literature Review

To get a determined and assessed valuation of projects, which mainly focuses on the cost of dealing with the restoration of the ecosystem from the damage caused by the project, we first model the impact of several kinds of land-use projects on the ecosystem services. Then, we attempt to search for a lowest-cost solution of the dealing process and value the extra cost of the “cleanup work” according to this cheapest one.

2. General Assumptions

1. We don’t consider extreme weather conditions.

Since extreme weather conditions are rare and cannot be measured easily, so we don’t take it into consideration.\

3. Model A: Preparation Model

## 3.1 Model overview

In our first model, we do some preparation for our next work. The whole ecosystem is complex and various, so we first specifically classify the ecosystem into some individual parts in to accurately analyze a project’s impact. As different types of projects cause different levels and kinds of damage to the ecosystem services, we also classify several common land-use projects according to their main influence on different parts of the ecosystem.

## 3.2 The Sections of the Ecosystem

Considering the several patterns in which the projects affect the ecosystem, such as discharging sewage, releasing flue gases, polluting the solid, we classify the complex ecosystem into four sections: pedosphere, hydrosphere, atmosphere and biosphere.

The project can mainly limit the environment through these sections. However, their impact on one section may also affect another section later. For instance, while water pollution directly influences the hydrosphere, the pollution to the hydrosphere may later also have an impact on the biosphere and do damage to creatures. In this way, we research the influence pattern of the sections and get:

图片包含 文字

已生成高可信度的说明

**Figure 1** the relation between different sections

In our consideration, the atmosphere influences the ecosystem most for it does effort every second and contacts most with the living creatures, as we all need to breathe. So we rank the impact of the atmosphere on the ecosystem first level. Then, the hydrosphere also plays a role in the ecosystem for all the living creatures need water as well. For this reason, we also get their relative weight of their impact to the biosphere:

**Table 1** the relative Impact Weight of Spheres

|  |  |  |
| --- | --- | --- |
|  | Planets | Animals |
| Pedosphere | 1 | 0.5 |
| Hydrosphere | 1 | 1 |
| Atmosphere | 1 | 1 |

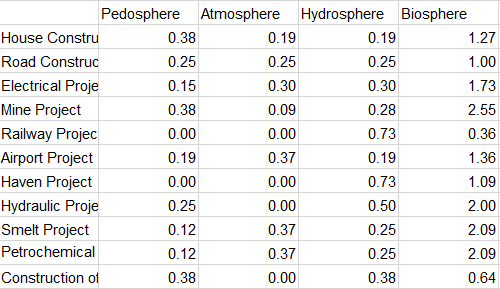
In this table, we divide the biosphere into the animals and the planets to get a more general weight of them. Then we get the expression:

In this expression, the is the weight of the project to certain sphere. In this way, we can get the impact on the biosphere.

## 3.3 The Classification of the Land-Use Projects

Obviously, different projects mainly influence one or several parts of the ecosystem. For this, we classify several common projects according to their influence to research the impact of a certain project and calculate the relative impact of them to different parts of the ecosystem:

**Table 2** the relative impact of the projects to different parts of the ecosystem



4.Model B: Evaluation for Impact

## 4.1 Model Overview

In this model, we will research for the standard to evaluate the polluted quality of the ecosystem so that we can qualify the impact of a land-used project to a certain area by comparing the evaluation index. We individually discuss the evaluation for four different parts of the ecosystem according to their different characteristics. Finally, we combine these four indexes and get the general evaluation value for an area.

## 4.2 Variable Table

**Table 3** Variable Table for Model B

|  |  |
| --- | --- |
| Variables | Definition |
|  | The water quality index |
|  | The actual measured index for a certain factor i |
|  | The expected value for a certain factor |
|  | The air quality index |
|  | The factors that influences the soil |
| κ | The osmotic coefficient |
|  | The water content in certain depth in soil |
|  | The total water content in soil |
|  | The evaluation index for chemical pollution of soil |
|  | The content of organic pollutants |
|  | The content of inorganic pollutants |
|  | The evaluation index for other pollutants in soil |
|  | The combined index for soil quality |
|  | The content of other pollutant like heavy metal and pesticide |
|  | The Simpson diversity index |
|  | The Shannon diversity index |
|  | The combined diversity index |
|  | The combined evaluation index for ecosystem |

## 4.3 Evaluation for the Water Quality

In most of present water qualification assessment, we often use the comprehensive assessment to evaluate the quality of the water. This could evaluate the water quality with regarding to various pollutants and get a relatively full-scale evaluation. The comprehensive assessment includes exponential evaluation method，fuzzy evaluation and others. In this essay, to get the accurate evaluation for the water, we use three methods of exponential evaluation to assess the water quality.

Before we combine all the factors that matters, we define the singer factor evaluation index for a specific factor:

In this expression, represents the quality index of water for factor . represent the actual measured value for the factor and represents the least allowable value for this factor.

Besides, for some specific factors, there are some special expressions:

This expression based on the Water environment quality standards promulgated by relevant departments in China. In this expression, represents the evaluate index for the dissolved oxygen, and represents the standard minimum concentration of dissolved oxygen. When , we regard the water environment as unpolluted.

For the evaluation parameter pH, when its concentration is 7.0, it shows that the water quality is in good condition. Excessive or low means pollution of different types. The calculation formula is as follows:

In the equation, and represents the Maximum concentration standard value and the minimum one.

### 4.3.1 Composite Index Analysis Method

First, we combine the evaluation index and get the simple express for the evaluation of the water quality:

In this equation, [arithmetic](javascript:;) [mean](javascript:;) [value](javascript:;) can objectively reflect the water quality.

### 4.3.2 Nemerow Method

However, the first method can only simply reflect the average quality of the water, having its consequence. Considering the weight of the maximum pollutant which influences the environment most, we use the Nemerow Method to reflect the pollution level of the hydrosphere exactly.

In this expression, the is the evaluation index for the most pollutant in this environment and the is the [arithmetic](javascript:;) [mean](javascript:;) [value](javascript:;) of all the pollutants.

### 4.3.3 Comprehensive Weight Analysis Method

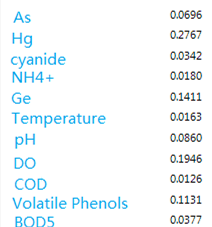
While the Nemerow Method underlines the weight of the maximum pollutant, the third method emphasizes the weight of all the pollutants.

In this method, we use the AHP to ascertain the weight of pollutants:

In this expression, should be the relative weight for the certain factor , for all the factors have different standard values and sensitivities.

In order to get the relative weight of different factors, we ascertain the weight matrix according to the ‘Quality standard for ground water’. By researching the standard range of the different pollutants, we can get the sensitivity level of the pollutants.

Then, we use the AHP and get the weight of eleven common pollutants:



To get an objective result, we take the arithmetic mean of these three results.

## 4.4 Evaluation for the Air Quality

The atmosphere usually affects the living things through the breathing process, so we use the Air Quality Index according to the national standard of China to evaluate the atmosphere’s environment.

In this equation, and should be the boundary value of a higher quality level and a lower one as and are their corresponding level. corresponds to according to the table below:

**Table 4** the standard for air pollutant and the corresponding weight

图片包含 纵横字谜

已生成高可信度的说明

Then we take the biggest and take the corresponding level to calculate the evaluation value for air quality.

## 4.5 Evaluation for the Soil Quality

In this model, we will discuss the evaluation for the soil quality. Researching for the indicators evaluating the soil quality, we divide them into three parts:

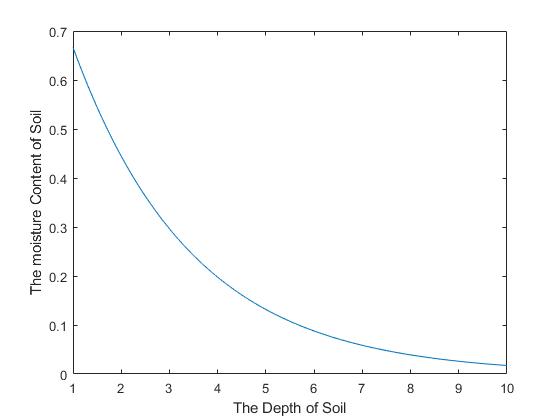
图片包含 屏幕截图

已生成极高可信度的说明

**Figure 2** Three parts of soil quality

### 4.5.1 The Physical Factors

First, we discuss the physical indicators. For land-used projects usually influence the osmolality and the thickness of the soil, we take these two indicators as the physical indexes. These two indicators can influence the growth of the planets by influencing the water content in the water, we can get their relation as the figure:



**Figure 3** Relation between osmolality and soil thickness

In this figure, the slope of the function represents the osmolality of the soil as it determines how deeply the water can infiltrate. And the slope itself will change as it goes deeper:

In the equation, is the permeability of the soil, is the fluid density, g is the [gravitational](javascript:;) [acceleration](javascript:;) and the is the dynamic viscosity coefficient.

Besides, the water content in certain depth also affected by the water content in the higher soil. In this way, we can get:

Then, we can get the expression of :

Then we can get the total water content of the soil as the physical indicator:

### 4.5.2 The Chemical Factors

The chemical indicator includes the organic matters, the soil pH and the inorganic fertilizer content. These three factors work together and affect the growth of the planet. We simply get the relation between them:

For these factors are all important to the growth of a planet, this simple expression can also reflect their interplay effect.

### 4.5.3 The Pollutants

Finally, we calculate the impact of the pollutants. For projects only cause heavy metal pollution and some other pollution, we take these two factors into our consideration：

In this equation, and are the [weight](javascript:;) [coefficient](javascript:;)s of the heavy pollution and other pollution. We can calculate them according to the sensitivity of the standard value.

**Table 5** The Standard Value for Pollutants

图片包含 屏幕截图

已生成极高可信度的说明

Finally, we can get the combined index for soil quality:

## 4.6 Evaluation for the Biosphere

Commonly, we evaluate the quality of the biosphere by the biodiversity of the biosphere. We use two common diversity indexes to reflect the biodiversity to evaluate the biosphere.

### 4.6.1 The Simpson Index

The Simpson Index is the possibility to measure the degree of concentration when individuals are classified into types. It also equals the probability that two entities taken at random from the dataset of interest represent the same type. We usually use it to describe the diversity of an environment. We can get it by the equation:

The is the proportion of individuals in a community to the total number of individuals, and the is the total number of types in the environment.

### 4.6.2 The Shannon Index

The Shannon Index is also often used as a diversity index. We can get the Shannon Index through the expression:

Then we get a comprehensive diversity index by calculating the [arithmetic](javascript:;) [mean](javascript:;) of these two indexes:

## 4.7 The Evaluation Index for the Ecosystem

In this way, we can get the final evaluation index for the whole ecosystem:

Since the least qualified value of each individual factor is 1, so the least qualified value of the whole formula is 3.

## 4.8 Model Conclusion

To examine our model, we choose Qingpu port in Shanghai and calculate that its final evaluation index is 0.985. According to the standard of China, the least qualified value should be 3. In this way, we can get that this site is far below the standard.

5. Model C: The Valuation for the Cost

## 5.1 Model Overview

In this model, we will value the impact of a project to the nearby environment. We research the factors such as the area of a project, the industrial density of the project, the local quality of technology and others. According to these factors and the type of a project, we can get an assessed and accurate impact of a project on the nearby ecosystem and ascertain the cost of the “cleanup work”.

## 5.2 Model Assumption

1. We consider the acceleration of wind speed and water speed to be zero in a short time.

Since the atmosphere and water are incompressible fluids, we consider the acceleration to be zero for very short periods of time.

## 5.2 Constants and Variables

**Table 6** The variables for Model C

|  |  |
| --- | --- |
| Variables | Definition |
|  | The qualified impact on sphere |
|  | The time |
|  | The area of the project |
|  | The distance from a site to the project area |
|  | The exploitation degree of the project |
|  | The original quality of the environment |
|  | The technology quality of the project |
|  | The population of city i |
|  | * The Equivalent charge of the chemical pollutant |
|  | * The velocity of propagation of particles |
|  | The concentration of the propagation |
|  | The diffusion coefficient which equals to |
|  | The mass flux of a certain area |
|  | The mass of the propagation |
|  | The distributed concentration of the propagation |

## 5.3 The Total Expression

Common land-used projects first influence the pedosphere. Obviously, the closer it is to the project area, the more it will be affected by the activity. In this way, we can get the impact drops off as the distance increases.

The impact radiates to its nearby area from the activity area and declines as it goes farther. In this way, we first model the relation between the quality of the impact and the distance.

Then, we can calculate the total impact of a radiation by integrating its impact over the distance.

In the equation, is the weight of the factor, which has been discussed in the preparation model.

In this way, we get the total impact quality of a particular project area to the near environment:

Besides, time should be taken into our consideration.

## 5.4 Constructing Impact

In constructing process of a land-use project, we consider the factors that may determine the impact on the soil. In our research, we consider that the exploitation degree, the original quality of the environment, the area and the technology quality will determine impact, for the environment will be easier to damage with a low quality. In this way, we get the figure of their relation:

图片包含 文字, 地图

已生成极高可信度的说明

**Figure 4** The Change of the Constructing Impact

In this figure, we can get that the y-intercut of the function should be , and the slope of the function should be , for it drops faster with a lower quality of technology and a worse organic environment. In this way, we can get the x-intercut of the function should be .

Then, we can get expression of a project’s constructing impact:

In this equation, we use the impact of all the project area to evaluate the final constructing impact. And we calculate the index of technology through the proportion of research expenditure in local GDP:

## 5.5 Impact on Pedosphere

According to the total evaluation, we define the evaluation for impact on soil:

The projects often influence the soil by releasing chemicals pollutants that may change the pH of the soil and some other pollutants which may also do harm to the soil quality. In this section, we compare the spread of the chemical pollutants to the movement of electric charge in an electric field.

图片包含 文字, 地图

已生成高可信度的说明

**Figure 5** the change of water content

In this figure, we can get that when the pollutant spreads, it receives a resistance from the soil which is determined by the osmotic coefficient of the soil, a gravity and a Lorentz force caused by the geomagnetic field. In this way, we can get:

By solving this equation set, we can get the express for the  and :

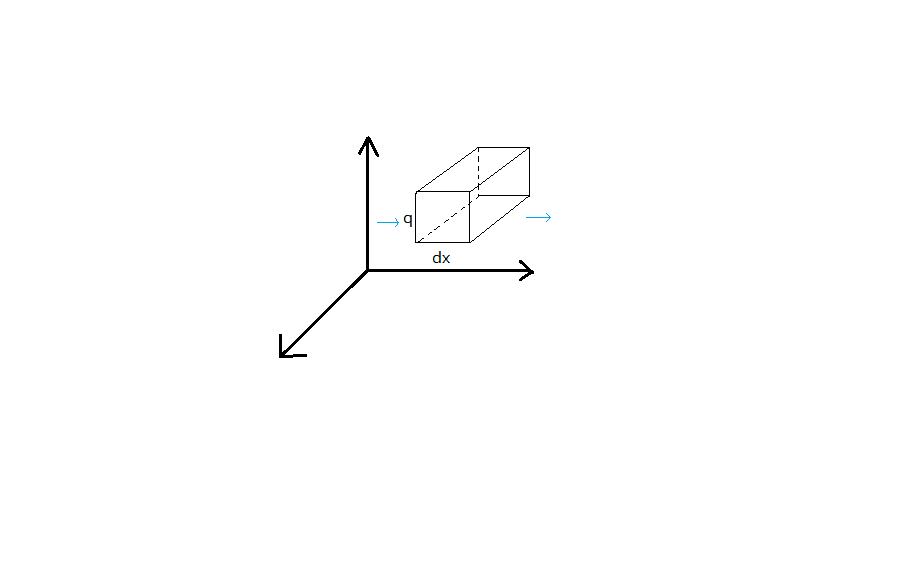
Then, we can get the final expression for :

In this model, we ascertain the quantity of electric charge based on its pH, for the pH determines the concentration of the positive or the negative ions which influences the Lorentz force of the pollutant. In this way, we get the expression:

In this expression, the is the Elementary charge which equals to .

## 5.6 Impact on Hydrosphere

Then we will discuss the spread of pollutant in the hydrosphere. When the pollutants are transported through the water, there are also some pollutants depositing in the water.



**Figure 6** the spread of the pollutant in water

In this way, we can get the expression:

In the equation, is the depositing pollutant and the is the transported pollutants without depositing. Then we get the real transported pollutants:

Then, for the total quality of the water remains the same, we can get:

Then we combine these two equations and get:

Then, for water is a kind of liquid that can’t be compressed and has consecutiveness, we can get that:

In order to get the expression, we construct a function:

Then, for the function conform to the condition:

Then we can get the express for :

For the concentration of a pollutant varies continuously, we can get:

For is an index including the quality of the pollutant, we get the relative concentration index:

Through this equation, we can get that the concentration is normally distributed. Then we calculate the total evaluation index :

Besides, considering the pushing force of the water itself, the distance should plus the distance pushed by the current:

For the concentration of the pollutants is normally distributed in the water, we calculate final evaluation for the impact on the hydrosphere by integrating the peak value of the concentrations:

## 5.7 Impact on Atmosphere

As we have confirmed in the model above, when the particles spread, its concentration is normally distributed. In this way, we can get the distribution function of the pollutants in the atmosphere:

Then, we can get the total quality of pollutants :

In this equation, the is the speed of the wind, as the wind helps the pollutants spread.

When there are two sites that are the same distance from the project area, their pollution level should also be the same. Because of this, we think that the distribution of the pollution level fits the distribution of a sphere.

Then, we can get the evaluation index:

## 5.8 Impact on Biosphere

For we have researched the impact of the different spheres to the biosphere and get their relative weight, we can get the evaluation index for impact on biosphere by combining them:

## 5.9 The Valuation for the “Extra”

We consider the economic equivalent of environmental damage in terms of products, productivity, disease and death, and we get the following three basic equations:

Products:

In which, means the profit, means the cost of the products, and q means the number of the products that has been sold.

Productivity and disease:

In which, means the profit a person should have made, means the cost of curing the disease.

Death:

In which, means the death rate, means the profit a person should have made.

But the parameters in the equation are hard to come by so we need to do some preparatory work to transform the equation.

At first, the death rate should distribute as the figure:

图片包含 地图

已生成极高可信度的说明

**Figure 7** The death rate distribution

So we can fit the function:

Then, we get the total death rate:

Then we substitute the death rate in 2017 into the equation and get , and we call this distribution

And we can get the change of the resistance power of a person:

图片包含 地图, 文字

已生成高可信度的说明

**Figure 8** the change of the resistance of a person

And we get the distribution of the resistance:

And we define this distribution as

Then, we can get the change of the death rate:

And the profit is proportional to the local GDP.

Then, we change the equation of productivity and disease, we consider that the profit is proportional to the local GDP, and the cost of the disease is proportional to the death rate.

And the profit of the products is proportional to the environment.:

And we add them together to get the result.

6. Sensitive Analysis

In this essay, we take constant D and κ and change their values to examine the stability of our model.

图片包含 文字, 名片

已生成高可信度的说明

**Figure 9** the sensitive analysis

Through the figure below, we can get that our model is stable and credible.

7. Strengths and weaknesses

**Strengths**

1. **Our model is considerate and comprehensive**

*Our model takes many factors into our consideration and discuss plenty of relations between them, which makes our model comprehensive and considerate.*

1. **Our model is common**

*For we have considered many of the factors, such as the geomagnetic field’s change in different site of the earth.*

**Weaknesses**

1. **Our model is too complex.**

*Complexity of our model provides some difficulties in calculating and simulating, which actually took us a long time.*

1. **Our model has too many constants.**

*The existence of constants may cause instability of our conclusion, as well as make it far more difficult to apply our model to predict.*

9. References

[1] Application of the Composite Index Analysis Method to the Assessment of the Huanggang River, Linkun Ming, Zhao Jian, 1006-7175(2008)03-0203-02

[2] Section water quality analysis of qingpu qushui port in Shanghai

*http://datacenter.mep.gov.cn*

[3] Dichlorodiphenyltrichloroethane

*https://en.wikipedia.org/wiki/DDT*