Contents

1. Introduction

1.1 Background

The various benefits, which human obtain from the ecosystem, are collectively referred to as ecosystem services[1]. The related researches in this field have made great progress in recent decades. Especially after the United Nations Millennium Assessment, the value assessment of ecosystem services and its relationship with human have been confirmed in academic world and more and more researchers have paid attention on this field[2]. With the development of economy, there are more and more land use projects, such as laying pipelines, building houses, building factories, etc. However, in most cases, we often ignore its impact on the ecosystem, when the cost of a project is estimated. For instance, whenever the ecological system is changed, some factors including climate regulation, water conservation, soil formation and protection, waste treatment, food production, culture and so on, are likely to be restricted or eliminated, which will lead to global warming, biodiversity reduction and directly endanger the human living environment

The impact of small projects, like local small-scale land-use change including building some roads, sewers, bridges, departments or factories, may seem insignificant. Besides, large projects, such as the construction or relocation of large corporate headquarters and pipelines across the country or the expansion or alteration of waterways to expand commercial USES, cumulatively directly affect the biodiversity, lead to an environmental degradation, even trigger natural disasters such as earthquakes, while they may not be relevant to the overall operational capacity of the biosphere[3-4].

Lucid waters and lush mountains are invaluable assets. Hence, we should not build projects and develop the economy at the expense of ecosystem services and Our land use projects should be combined with our environmental protection. In addition, in the process of land use project development, we should not only take the maximum benefit as the sole criterion, but also bear a certain cost of environmental protection to make up for the loss caused by environmental degradation.

1.2 Restatement of the problems

Firstly, in order to study the cost of environmental degradation, we set up an ecosystem service evaluation model to obtain the real economic cost of land use projects, and then analyze and calculate the real cost-benefit ratio of land use projects.

Our team also complete the following tasks:

1. Establish an ecological service evaluation model to obtain the real economic cost of land use projects under ecosystem services.
2. Use this model to analyze the cost and benefit of different scales of land use development projects from small community projects to large national projects.
3. Evaluate the effectiveness of this model according to the analysis and model design.
4. Give some related suggestions to land use project planners and managers basing on this model.
5. The changes of this model over time.

2. Basic Assumption

In order to build this model, we need to make several basic assumptions first.

1. The project in the model brings direct economic benefits and environmental impacts in the life cycle and it does not involve the potential value brought after completion.
2. If there is no ecological environmental protection measures, the environment in the region will be completely degraded, that is, the ecosystem service value in the

region will eventually be 0.

3. The cost of cement, gravel, steel reinforcement, vehicles and labor used in the construction process of land use projects are all calculated as the same, which are not related to the project scale, that is, the unit area construction cost is a fixed value.

4. The real function of model types of ecosystem service degradation and environmental protection on environmental recovery are measured in monetary terms ($).

5. The environmental degradation costs of the projects in the model through accumulation over the life cycle may trigger extreme conditions, such as earthquakes and other natural disasters.

6. Before the project construction, the environmental degradation degree is 0 and the environmental service value is 100% in the model.

3. Notation

Symbols	Explanation
$A_k (k = 1, 2, \cdots, 6)$	Area of six ecosystems in land use projects(ha)
$P_{kl} (k, l = 1, 2, \cdots, 6)$	Price per unit area of ecosystem service function *j* of category *k* ecosystem services($/ ha)
ESV	Ecosystem Service Value of Land Use Projects ($)
X	Environmental Protection Cost of Land Use Projects ($)
A	Ecosystem environmental costs($)
B	Construction Cost of Land Use Projects ($)
W	Real Economic Cost of Land Use Projects ($)
S	Income from Land Use Projects ($)
∂	Profit conversion ratio
r	Cost-benefit ratio of land use projects

4.Model Establishment

In this paper, the ecosystem service value of 14 factors, using principal component analysis for dimension reduction processing integrated impact index, refer to the average value of annual global ecosystem services (see appendix 1) get six terrestrial ecosystem per unit area ecosystem service value, according to the ecosystem area set up ecosystem service value assessment model. At the same time, investment in environmental protection during land development reduces the loss of ecosystem service value (degradation cost). Therefore, ecological cost is composed of degradation cost and environmental protection cost. The real economic cost of land use project is the sum of ecological cost and construction cost. We use this model to analyze small-scale projects and large-scale projects respectively. Then the model is analyzed and evaluated with examples of projects of different scales. According to the cost-benefit model of task 2 and the verification results of task 3, reasonable Suggestions are put forward to the person in charge of the land use project to achieve a win-win situation of reducing the cost of ecological degradation and reducing the cost-benefit ratio. Finally, we analyze the time of the model.

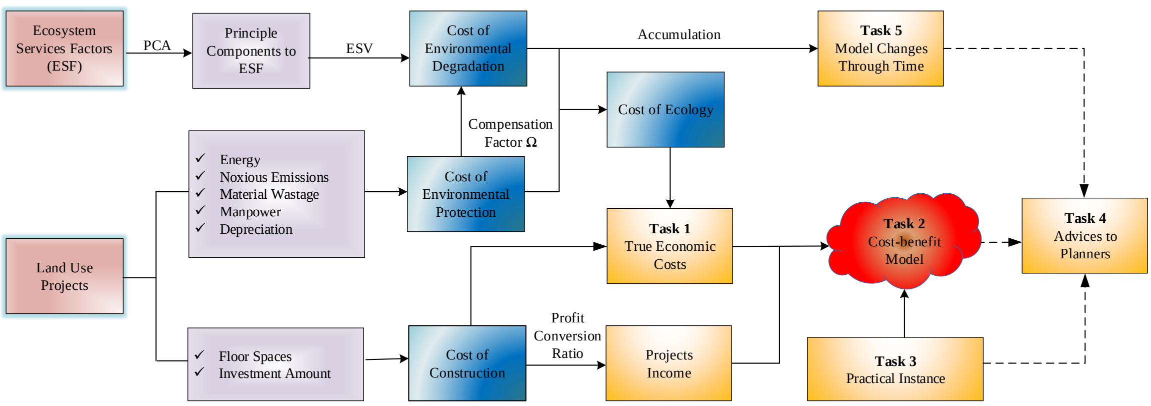

Figure 1 Illustration of ecological service valuation model

4.1 Land use cost model based on ecological service assessment

4.1.1 The ecosystem service value cost model of land use project

First step: Determination of evaluation index of regional ecosystem service value

Methods ：

Primary indicators selection → Dimensionality reduction → Composite index (principal component)

(1) Primary indicators selection

Costanza published an article in the journal *Nature* in 1997, *the global value of ecosystem services and natural capital*. In this essay, he assumed that ecosystem services in supply and demand curve is a vertical straight line and then estimated value of ecosystem services in various ecosystems, which clarifies the principle and method of ecosystem services value estimation.

This paper focuses on land use projects, that is, it only focuses on terrestrial ecosystems. According to the biological community statistics table in annex 1, we have summarized the global terrestrial ecosystem into 6 types: woodland, grassland, farmland, wetland, water body and desert. And 14 indicators were determined to depict the ecosystem services value, including air adjustment, climate regulation, disturbance regulation, water adjustment, water supply, erosion control, soil formation, nutrient cycling, waste disposal, pollination, biological control, habitat/shelter, food production, raw materials, genetic resources, leisure, culture, etc, which were referred as $x_i(i=1,2,\cdots,m)$ ， m=14。

(2)Standardize the raw data

In annex 2, the index values of m (m=14) indicator variables and n (n=11,225) evaluation objects were standardized.

The j th index value of the i th indicator of the evaluation object is a_{ij} and The standardized index value is a_{ij} , and we could calculate the a_{ij} :

$$a_{ij}=\frac{a_{ij}-u_j}{s_j},i=1,2,\cdots,n;\ j=1,2,\cdots,m \tag{1}$$

In the formula,

$$u_j=\frac{1}{n}\sum_{i=1}^{n}a_{ij},\ j=1,2,\cdots,m,\quad s_j=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(a_{ij}-u_j\right)^2},\ j=1,2,\cdots,m \tag{2}$$

The sample mean of the j th index is u_j and s_j is the sample standard deviation of the j th index, and we could calculate the standardized index variable x_j.

$$x_j=\frac{x_j-u_j}{s_j},\ j=1,2,\cdots,m \tag{3}$$

(3) Calculate the correlation coefficient matrix R

Define the correlation coefficient matrix $R=\left(r_{ij}\right)_{m\times m}$, which is the correlation coefficient between the i th index and the j th index. The calculation formula is as follow.

$$r_{ij}=\frac{\sum_{k=1}^{n}a_{ki}\bullet a_{ki}}{n-1},i,\ j=1,2,\cdots,m \tag{4}$$

In the formula, $r_{ii}=1,r_{ij}=r_{ji}$ 。

(4) Calculate eigenvalues and eigenvectors

Calculate the eigenvalues of the correlation coefficient matrix R : $\lambda_1\geq\lambda_2\geq\cdots\geq\lambda_m(\lambda_i\geq0)$ and the corresponding eigenvectors u_1 , u_2 ,…, u_m , and $u_j=\left[u_{1j},u_{2j},\cdots,u_{nj}\right]^T$. The eigenvector constitutes m new indicator variables:

$$\begin{aligned}y_1&=u_{11}x_1+u_{21}x_2+...+u_{m1}x_m,\\ y_2&=u_{12}x_2+u_{22}x_2+...+u_{m2}x_m,\\ &\vdots\\ y_m&=u_{1m}x_1+u_{2m}x_2+...+u_{mm}x_m,\end{aligned} \tag{5}$$

In the formula, y_i is the i th principal component and $i=1,2,\cdots,m$.

(5) Determine the comprehensive evaluation index

Calculate the information contribution rate and cumulative contribution rate of eigenvalues $\lambda_j\left(j=1,2,\cdots,m\right)$.

The information contribution rate of the principal component y_j is

$$b_j=\frac{\lambda_j}{\sum_{k=1}^{m}\lambda_k},\ j=1,2,...,m \tag{6}$$

The cumulative contribution rate of the principal component $y_1,\cdots,y_p$ is

$$\alpha_p=\frac{\sum_{k=1}^{p}\lambda_k}{\sum_{k=1}^{m}\lambda_k} \tag{7}$$

When α_p is close to 1, the p former indicator variables $y_1,\cdots,y_p$ are selected as p principal components to replace the original m indicator variables, and then we could conduct a comprehensive analysis of the p principal components.

(6) Index selection results

The *Matlab* software was used to conduct principal component analysis on the 14 evaluation indexes. All characteristic values and contribution rates of the correlation coefficient matrix are as follows:

Table 1 Results of Principal Component Analysis

order number	eigenvalue	contribution rate	cumulative contribution rate
1	5.14027	36.71626	36.71626
2	2.14108	15.29349	52.00976
3	1.49827	10.70199	62.71175
4	1.18746	8.481912	71.19367
5	1.14271	8.162226	79.35589
6	0.93465	6.676072	86.03196
7	0.49801	3.55723	89.58919
8	0.41133	2.93809	92.52728
9	0.35775	2.55536	95.08264
10	0.24662	1.76154	96.84418
11	0.18145	1.29605	98.14023
12	0.17355	1.23965	99.37988
13	0.06656	0.47540	99.85528
14	0.02026	0.14472	100

The first six principal components whose cumulative contribution rate is close to 90% are selected for comprehensive evaluation, and the corresponding feature vectors are as follows:

Table 2: The eigenvectors corresponding to the first six principal components of a normalized variable

NO	1	2	3	4	5	6
x_1	0.37024	0.35826	0.35451	0.22732	0.25397	0.05588
x_2	0.26190	0.20283	0.17476	-0.02692	0.13755	0.00046
x_3	0.16783	0.10358	-0.07997	0.08340	-0.24543	0.14336
x_4	0.09395	-0.15875	0.09455	0.59231	-0.46524	-0.31884
x_5	-0.00268	0.00598	-0.17486	0.06616	-0.34865	0.76360
x_6	0.04139	-0.04142	-0.17679	0.43738	0.04359	0.34323
x_7	-0.10515	0.19280	0.10750	0.28611	-0.00752	0.00964
x_8	0.26277	-0.03410	-0.15275	-0.31890	-0.44840	-0.17293
x_9	-0.16151	0.13028	0.54231	-0.10298	0.05607	0.30730
x_{10}	-0.04596	0.84792	-0.32484	-0.04952	-0.17933	-0.12642
x_{11}	0.24585	-0.07502	-0.08904	-0.39480	0.00919	0.18060
x_{12}	-0.06539	0.05071	0.56886	-0.19560	-0.52609	-0.00641
x_{13}	0.76321	-0.09858	0.02309	0.01833	0.04315	0.02393

x_{14}	0.01030	-0.02511	-0.00626	0.05527	0.03599	0.01178

The selection of principal components has comprehensiveness (it can reflect most of the information of the original variables) and independence (the contained information is not repeated).

To sum up, the six indicators that represent the environmental cost assessment of land use projects are: climate regulation, water conservation, soil formation and protection, waste treatment, food production and culture.

Second step: Establishment of regional ecosystem service value (degradation cost) model

According to the data in annex 1 and the questionnaire of nearly 200 ecologists, the unit area value table of 6 main indicators in 6 terrestrial ecosystems can be obtained.

Table 3: Table of global ecosystem services per unit area of different terrestrial ecosystems ($/hm^2)

Ecosystem Service	woods	grassland	farmland	wetland	water	desert
Climate regulation	341.3	113.8	112.5	2161.6	58.1	0.0
Water conservation	404.5	101.1	75.8	1959.3	2576.2	3.8
Soil formation and conservation	493.0	246.5	184.6	216.2	2576.2	2.5
Waste disposal	165.6	165.6	207.3	2298.0	2298.0	1.3
Food production	12.6	37.9	126.4	37.9	8.8	1.3
Culture	161.8	5.1	1.3	701.6	548.6	1.3

According to the unit area price $P_{kl}(k,l=1,2,\cdots,6)$ of the j$_{th}$ ecosystem service function of the k-type ecosystem service (USD/ha), the value of regional ecosystem service (degradation cost) ESV model is obtained by multiplying and summation with the area $A_k(k=1,2,\cdots,6)$ of various ecosystems in the region (ha).

Model 1: Regional Ecosystem Service Value (Degradation Cost) ESV Model:

$$ESV=\sum_{k=1}^{6}\sum_{l=1}^{6}A_kP_{kl} \tag{8}$$

4.1.2 Environmental Protection Cost Model of Land Use Project

In most cases, land use projects do not take into account of the impact of ecosystem services. No matter the project size is large or small, and no matter what type it is, it will have an impact on the environment. According to formula (8), this will directly affect the value of ecosystem services. To reduce the negative impact of land use change, we will consider investment from five aspects, energy, harmful emissions, material loss, manpower and depreciation, to compensate for the impact of project construction on the ecological environment, when land use projects take into account ecosystem services.

(1)The establishment of environmental protection cost model of land use project

Step1 Analysis of influence factors

① Energy

The ecological cost of energy is the cost of replacing the current fossil energy with renewable energy, which can be regarded as the price of renewable energy. The energy in the construction phase contains electric energy, diesel oil, gasoline.

(a) electricity

The burning of fossil energy will release a large amount of acidic gas, causing environmental problems. As a result, renewable energy generation boosts dramatically, including hydropower generation, wind power generation, solar power (pv) generation and so on. Considering that there are assorted methods of generating electricity from renewable energy and the costs vary from one to the other, we put the proportion of each clean energy use into account when calculating the ecological cost of electric energy. And the weighted average method can be used to calculate the integrated unit ecological cost of electric energy. The calculation formula is as follows:

$$C_{ed} = \sum_{i} M_i \times R_i \tag{9}$$

Where, C_{ed} (\$) represents the environmental protection cost of electric energy; M_i (\$/*kj*) is the unit generation cost of the i th kind of renewable energy; R_i is the proportion of i th power generation corresponding to the second type of renewable energy in the total power generation; A_{ed} is power consumption. Table 4 shows us the Global Status Report statistics of the proportion of all kinds of renewable energy power generation in the world in 2015.

Table 4: Proportion and cost of renewable energy generation in 2015

Energy	hydropower	wind energy	biomass energy	photovoltaic	ocean energy	geothermal energy
Power ratio	73.0%	14.0%	8.0%	4.0%	0.5%	0.5%
Power generation cost	0.29	0.60	0.69	0.98	2.68	0.37

Calculated by the formula 9，the ecological cost of electricity is C_{ed} =0.41.

(b) Gasoline and diesel oil

In the construction stage, the transportation and mechanical equipment operation need to consume a large amount of gasoline and diesel, which are secondary energy and made from the processing of primary energy, petroleum. Petroleum is a non-renewable fossil energy, so the use of gasoline and diesel will inevitably bring ecological load, and the corresponding ecological cost needs to be calculated.

When calculating the price and ecological cost of gasoline and diesel, the unit heat production price is taken as the unit, which needs to be converted by the calorific value (low calorific value) and density corresponding to energy.

The calculation formula of unit heat production price of fuel is:

$$P_o = P \times A_o / (q \times \rho) \tag{10}$$

Where, P_o (\$) is the heat production cost of fuel; P (\$/L) is the unit volume price of fuel; A_o is the fuel consumption; q (unit: MJ/kg); A_o is the low calorific value of fuel; q

(kg/L) is the fuel density.

②Harmful emissions

In an ecological cost system, harmful emissions can be classified as ecotoxicity in terms of chemical, physical or biological effects. The ecological cost of harmful emissions is the marginal cost of prevention of their various environmental impacts. The environmental impact of equivalent and characteristic units shown in the following table:

$$C_e = \sum_i \sum_j B_i \times D_{ij} \times C_{mij} \tag{11}$$

In an ecological cost system, harmful emissions can be classified as ecotoxicity in terms of chemical, physical or biological effects.

Where, C_e represents the environmental protection cost of harmful emissions generated during energy consumption; B_i Represents energy consumption of type *i*; D_{ij} represents the amount of the *j*th harmful emissions generated by the use of the *i*th energy source; C_{mij} represents the prevention cost of *j*th harmful emissions from *i*th energy source.

③Material loss

The calculation of ecological cost is based on the whole life cycle assessment. The recyclability of materials determines the ecological cost of materials. Material recycling is divided into two parts: recycling and reusing. Recycling is processing of used waste materials so that they can be reused. Recycling requires processing the materials into brand-new things. Reuse means re-use several times and the shape and other characteristics of the material do not change. Hence, the calculation of ecological cost is based on the whole life cycle assessment. The recyclability of materials determines the ecological cost of materials. Material recycling is divided into two parts: recycling and reuse. Recycling is the processing and processing of used waste materials so that they can be reused. Recycling requires processing the materials into brand-new things. Reuse means re-use, the shape of the material used, and other characteristics do not change, its essence is to extend the service life of materials or items. Therefore, the sum of material regeneration rate α and reutilization rate β is taken as the comprehensive recovery rate γ of the material.

$$\alpha + \beta = \gamma \tag{12}$$

Then the ecological cost of material loss is:

$$C_{em} = C_r \times (1-\gamma) \times A_{em} \tag{13}$$

Where γ represents the comprehensive recycling utilization rate of materials; $\gamma = 0$ when the material is non-recyclable; C_r represents the unit cost of materials; C_{em} is the environmental protection cost of material loss, but when the material is non-recyclable, the environmental protection cost of material loss is equal to the actual cost of the material. A_{em} represents the amount of recycled material.

④Human ecological cost

Human ecological cost is an indirect ecological cost, because people themselves do not impact the environment. But a part of the environmental load is related to people. The environmental load related to people in the construction mainly comes from the electricity consumption of lighting, air conditioning, computers and other office equipment, the gasoline and diesel consumption of traffic activities such as commuting, and the consumption of coal and natural gas brought by heating and catering. Therefore, the human ecological cost can be regarded as the ecological cost of the energy consumed by the staff and the ecological cost of the emissions generated with the energy consumption. The calculation formula of the human ecological cost is as follows:

$$C_h = \sum_i \sum_j L_i \times (D_{ni} + D_{ij} \times C_{mij}) \tag{14}$$

Where C_h represents the cost of environmental protection of human resources; L_i denotes the amount of ith energy consumed by personnel, including electric energy, gasoline, diesel, coal, natural gas, etc; D_{ni} is the unit ecological cost corresponding to ith energy type; D_{ij} represents the amount of the jth harmful emissions generated by the ith energy source; C_{mij} is the jth cost of prevention of harmful emissions of the ith energy.

⑤Depreciation

The object of the calculation of the ecological cost of depreciation is the fixed assets used in the production process of the product. In large-scale production facilities, the calculation method of the ecological cost of depreciation is similar to that in the general financial calculation. With calculating the ecological cost of a product, the calculation formula of the ecological cost of depreciation is as follows:

$$Z = \frac{Z_s}{N \times T} \times Y \tag{15}$$

Where Z represents the environmental protection cost of depreciation; Z_s represents the environmental protection cost of production equipment; T represents the average service life of facilities and equipment in years; N represents the annual output of the product, and Y represents the service time of the equipment in the construction stage in years.

Step2 The establishment of environmental protection cost model of land use project

Considering the above five influencing factors, the environmental protection cost of the project is defined as

$$X = C_{ed} + P_o + C_e + C_{em} + C_h + Z \tag{16}$$

Then we could establish:

Model 2 Environmental protection cost model of land use project

$$\begin{aligned} X = & \sum_i M_i \times R_i + P \times A_o / (q \times \rho) + \\ & \sum_i \sum_j B_i \times D_{ij} \times C_{mij} + C_r \times (1-\gamma) \times A_{em} + \\ & \sum_i \sum_j L_i \times (D_{ni} + D_{ij} \times C_{mij}) + \frac{Z_s}{N \times T} \times Y \end{aligned} \tag{17}$$

(2)Revision of environmental protection cost model in land use project

Energy consumption cost in land use projects is closely related to the renewable energy. The energy consumption cost has increased with renewable energy, but the regional ecosystem services value has certain compensation. For instance, the equipment cost of solar energy power supply is higher than coal power, so the cost of energy consumption is high. But the solar power's influence on the ecosystem service value is small, which is closely related to the project's cost of energy consumption. For the sake of simplicity, we believe that this effect is positively correlated, so the energy consumption cost is not all included in the ecological system environmental cost, and the part of the cost that is actually included in the environmental protection cost is corrected as follows:

$$(1-\Omega)X \tag{18}$$

Where Ω is the compensation coefficient of ecosystem service value, which decreases as a logarithmic function over time specifically:

$$\Omega = \frac{1}{\ln T} \tag{19}$$

(3)Establishment of ecosystem environmental costs

In conclusion, we can get

Model 3 Ecosystem Environmental Cost Model

$$A = ESV + (1-\Omega)X \tag{20}$$

4.1.3 The construction cost of land use project

The construction cost of the land use project (USD) is

$$B = \sum_{k=1}^{6} A_k \times P_{A_k} \tag{21}$$

Where, A_k (ha) refers to the project area; P_{A_k} (\$/ha) is the unit cost per hectare required for the project.

4.1.4 Real economic costs of land use projects

The total cost of land use project is the sum of construction cost and ecological environment cost:

$$W = A + B = ESV + (1-\Omega)X + B \tag{22}$$

Model 4 The real economic cost model of land use project

$$\begin{aligned} W = \sum_{k=1}^{6}\sum_{l=1}^{6} A_k P_{kl} + (1-\Omega)\Bigg[& \sum_i M_i \times R_i + P \times A_o / (q \times \rho) + \\ & \sum_i \sum_j B_i \times D_{ij} \times C_{mij} + C_r \times (1-\gamma) \times A_{em} + \\ & \sum_i \sum_j L_i \times (D_{ni} + D_{ij} \times C_{mij}) + \frac{Z_s}{N \times T} \times Y \Bigg] + \sum_{k=1}^{6} A_k \times P_{A_k} \end{aligned} \tag{23}$$

4.2 Cost-benefit ratio model for land use projects

4.2.1 Standard for dividing the scale of land use projects

The area of six ecosystems occupied by land use projects $A_k (k = 1, 2, \cdots, 6)$ The total area M (unit：hectare)of the project can be obtained.

$$M = \sum_{k=1}^{6} A_k \tag{24}$$

According to the standards of most national construction departments for the scale of construction projects, when $M \geq 10$(hectares), the land use project is called a large-scale project; When $M < 10$ (hectares), the land use project is seen a small-scale project.

4.2.2 Cost-benefit ratio model for land use projects

The income of land use project is closely related to its cost. When the total investment of the project increases, the income of the project increases. Moreover, according to a large number of effective data, it can be considered that the income of land use project is proportional to the cost of the project. Suppose ∂ is the profit conversion ratio, so the income S (\$) of the land use project is

$$S=\partial \times B \tag{25}$$

Get the formula
$$r=\frac{W}{S} \tag{26}$$

put into equation（23）（25）, Get the formula

$$r=\frac{1}{\partial}\left[\sum_{k=1}^{6}\sum_{l=1}^{6}A_k P_{kl}+(1-\Omega)\left[\sum_i M_i \times R_i + P\times A_o/(q\times\rho)+\right.\right.$$
$$\sum_i\sum_j B_i \times D_{ij}\times C_{mij}+C_r\times(1-\gamma)\times A_{em}+ \tag{27}$$
$$\left.\left.\sum_i\sum_j L_i\times(D_{ni}+D_{ij}\times C_{mij})\right]+\frac{Z_s}{N\times T}\times Y\right]\times\frac{1}{\sum_{k=1}^{6}A_k\times P_{A_k}}+\frac{1}{\partial}$$

Therefore，The cost-benefit ratio model of land use projects established in this paper considering the value of ecological services is

Model 5 Cost-benefit ratio model for land use projects

$$r=\frac{1}{\partial}\left[\sum_{k=1}^{6}\sum_{l=1}^{6}A_k P_{kl}+(1-\Omega)\left[\sum_i M_i \times R_i + P\times A_o/(q\times\rho)+\right.\right.$$
$$\sum_i\sum_j B_i \times D_{ij}\times C_{mij}+C_r\times(1-\gamma)\times A_{em}+ \tag{28}$$
$$\left.\left.\sum_i\sum_j L_i\times(D_{ni}+D_{ij}\times C_{mij})\right]+\frac{Z_s}{N\times T}\times Y\right]\times\frac{1}{\sum_{k=1}^{6}A_k\times P_{A_k}}+\frac{1}{\partial}$$

According to formula (28), we get the relationship curve between the final cost-benefit ratio and the project area (Figure 2)。

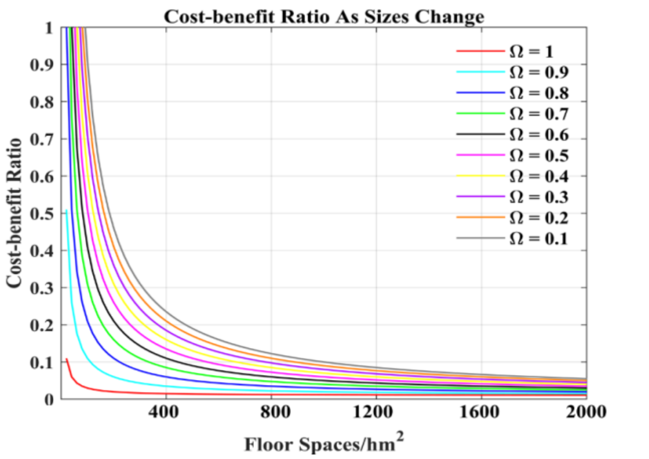

Figure 2: The influence of floor area
on the cost-benefit ratio of land use projects

According to figure 2,

Conclusion 1: When the compensation coefficient of ecosystem service value Ω remains unchanged, the cost-benefit ratio decreases with the increase of land use project area. At the initial stage of land area increase, the cost-benefit ratio decreases rapidly. In the later period in the land area increases, the cost-benefit ratio decreases at a slower rate and finally tends to a constant value.

Conclusion 2: The cost-benefit ratio of land use projects with the same land use area decreases with the increase of the compensation coefficient of ecosystem service value Ω when the land use area remains unchanged. With the process of increasing land use project area, Ω increasing, the variation trend of cost-benefit ratio is gradually increasing to a critical value and then decreasing.

Conclusion 3: With $\Omega \approx 1$, the invested environmental protection cost can protect the environment to a greater extent. And the cost-benefit ratio decreases faster, and the minimum value $r_{\min}$ can be reached.

4.2.3 Analysis of land use and development projects of different scales

Assume that the environmental protection costs of land use projects are the same no matter what size of projects is. So model 5 is simplified as follows:

$$r = \frac{1}{\partial}\left[\sum_{k=1}^{6}\sum_{l=1}^{6} A_k P_{kl} + (1-\Omega)C\right] \times \frac{1}{\sum_{k=1}^{6} A_k \times P_{A_k}} + \frac{1}{\partial} \tag{29}$$

The relationship between r values and $\sum_{k=1}^{6} A_k$ can be analyzed.

(1) If small projects and large projects only occupy the same ecosystem, so

$$r = \frac{1}{\partial}\left[A_k P_{kl} + (1-\Omega)C\right] \times \frac{1}{A_k \times P_{A_k}} + \frac{1}{\partial} \tag{30}$$

Obviously, the larger the project area is, the larger the project scale is, and the smaller the cost-benefit ratio is.

(2) If both small and large projects occupy only one ecosystem and the ecosystem is different, the type of ecosystem and the area of the project need to be considered comprehensively. If the value difference of ecosystem per unit area is too large, such as farmland (112.5) and wetland (2161.6), it should be analyzed on $A_k P_{kl}$ and $A_k \times P_{A_k}$ according to the value of each project. While if the value difference of ecosystem per unit area is small, such as farmland (112.5) and grassland (113.8), the larger the project area is, the larger the project scale is, and the smaller the cost-benefit ratio is.

(3) If a small project occupies only one ecosystem, and a large project occupies two or more similar ecosystems, the larger the project area is, the smaller the cost-benefit ratio will be.

Due to their limited scale, small construction costs and loss of ecosystem service value are few, which results in less environmental degradation costs. For large projects, due to the huge amount of capital, wide land occupation area and multiple ecological types, the ecological degradation cost of the project is large and complex. However, if the world's land area is used for small projects, their impact on ecosystem services will continue to accumulate, and the huge cost of environmental degradation will dramatically affect the value of ecosystem services, which leads to unpredictable even devastating effects on the biosphere on which we depend.

When large projects and small projects are changed in the same scale at the same time, the environmental degradation caused by small projects will change dramatically with the change of capital and land use, resulting in a sudden change of cost-benefit ratio. For large projects, because they have invested a large amount of money to produce high benefits, even with the increase of their scale, the benefits will not change a lot in a short time, so the benefit ratio of large projects is relatively stable.

4.3 Evaluation of the Effectiveness of the Model

By referring to a large number of literatures, we obtain the engineering design features of a real estate high-rise residential unit project in nanjing, China from this paper[5].

1) The construction structure of this project is frame shear wall structure;

2) The seismic rating of the building is class c, and the seismic fortification intensity is 6 degrees;

3) The project's building fire rating is level 2, and the building structure safety rating is level 2;

4) The reasonable service lifespan of the project is 50 years;

The total investment of the project is $276,0288.69, of which the construction cost is $251,5989.474. This project has a common construction type and structure, and no special requirements for construction technology. Therefore, the calculated ecological cost and EVR data can be used as a reference for similar high-rise residential projects.

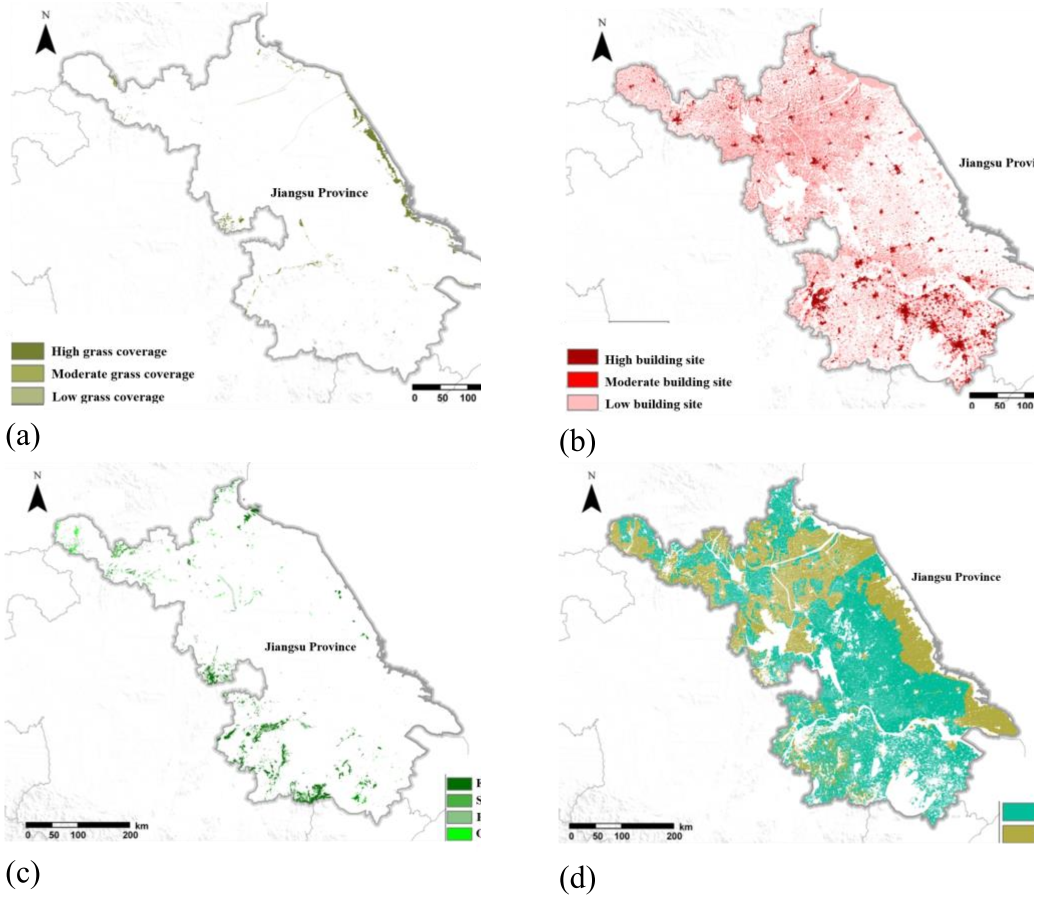

Figure 3:
(a) shows the occupied area of grass land in jiangsu province
(b) the occupied area of existing building land in jiangsu province
(c) shows the current occupied area of deep forest in jiangsu province
(d) shows the current occupied area of cultivated land in jiangsu province

This project has a building area of 1.680832855 hm^2 and an area of 0.07640932 hm^2. It covers various ecosystem types, forest (50.47%), grassland (5.76%), wetlands (43%), farmland (0%) and water (0.77%). The land use ecosystem services value can be calculated by formula (8).

Table 6 The ecosystem service value of the land use project

	Woodland	grassland	farmland	wetland	water body	total
Area ratio (%)	50.47	5.76	0.00	43.00	0.77	100
Area (ha)	0.0385	0.0044	0	0.0328	0.0006	0.0764
Ecosystem services value (usd)	993.88	26.97	0	6448.81	0.28	7469.95

Combined with the local housing price, the profit from the construction cost can be calculated: $1680,832.85, which is 6.08933 times of the total investment, and the total environmental investment accounts for 0.47868% of the project. It can be concluded that China's GDP in 2013 is 90,001328.6 billion dollars by Chinese Ecological Environment Report among 2006 to 2013, in which the sum of virtual governance cost, environmental degradation cost, ecological damage loss cost and ecological environmental degradation cost is 6867.02857 billion us dollars, accounting for 7.63%.

In 2013, the cost of environmental degradation and ecological damage in China totaled $293.5414.3 billion dollars, an increase of 13.5% over 2012 and about 3.3% of GDP of 2013. Due to the lack of basic data, the accounting scope of various losses is not comprehensive; the loss of resource consumption is not accounted for; the cost of environmental degradation mainly lacks the data of soil and groundwater environmental degradation. Accounting report of ecological environmental degradation cost accounts for the proportion of about 3.1% - 3.9%. In the general urban construction, compared with comprehensive profit, environmental resources degradation percentage is a small even negligible value. But based on incomplete statistics of the country's environmental degradation database, the influence of environmental degradation will have a very big value as increasing with the base and quantity growth. So in the model, as the project increases gradually, the cost of environmental degradation climbs up gradually. And to a certain extent, environment degradation is permanent irreversible. Hence, environmental degradation can lead to a serious impact on a country when it comes together.

So environmental degradation cost in human life is a problem that cannot be ignored with maintaining the economic development. For the building project, ecological degradation costs accounts for 0.47868% of the project. And in the Development of China's Report, the ecological degradation costs accounts for 3.1% to 3.9% of GDP. With the increase of project scale, environmental degradation cost is higher and higher, which leads to lower cost benefit. With this situation, people need to input a certain proportion of budget as ecological protection cost and intervene cost of ecological degradation. Small projects also need to protect the ecology. In addition, Larger projects have to invest more capital in the protection of the ecological environment and try to slow down the time when the cost of environmental degradation reaches the critical collapse value.

4.4 Model recommendations for land use project planners and managers

Conclusion based on task two: Firstly, the company invests a certain amount of environmental protection cost to make up for the loss of environmental degradation cost caused by land occupation. Secondly, the cost-benefit ratio decreases with the increase of the project area. Meanwhile, in the initial stage of the increase of the project area, the cost-benefit ratio decreases rapidly. In the later period of the land area increases, the cost-benefit ratio decreases and slows down, and finally reaches a fixed value and remains unchanged. Therefore, there exists an area that makes the cost-benefit ratio and total cost reach the best level for the company.

1. Cost of environmental protection $<$ Cost of environmental degradation

The cost of environmental protection invested by the company is not enough to make up for the environmental damage caused by the company's occupation of land. For the same project, if it covers a certain area, the cost of environmental protection will be less and the construction cost will be increased. In this case, the income of the company will be increased. At this point, the company's decision makers can devote part of their income to the process of environmental degradation, so that the environment can be effectively protected as the company's profit increases.

2. Cost of environmental protection $=$ Cost of environmental degradation

The cost of environmental protection invested by the company will cover all the environmental damage. At this point, the balance is reached. The cost-benefit ratio of the company's project reaches the place where it declines the fastest, and the damaged environment is all effectively protected.

It is assumed that the cost of environmental protection can be fully utilized for environmental protection，That is, the compensation coefficient of ecosystem service value $\Omega = 1$

$$X = ESV \tag{31}$$

Substitute into formula (8), (16) to get：

$$\begin{aligned}&\sum_i M_i \times R_i + P \times A_o / (q \times \rho) + \\ &\sum_i \sum_j B_i \times D_{ij} \times C_{mij} + C_r \times (1-\gamma) \times A_{em} + \\ &\sum_i \sum_j L_i \times (D_{ni} + D_{ij} \times C_{mij}) + \frac{Z_s}{N \times T} \times Y = A_k \times P_{kl}\end{aligned} \tag{32}$$

According to formula (31) and (32), the area A_k occupied at this time is：

$$A_k = \frac{X}{P_{kl}} \tag{33}$$

The cost-benefit ratio is obtained by substituting A_k into equation 22：

$$r = \frac{P_{Ak} + \dfrac{(1-\Omega)X}{A_k} + P_{kl}}{\partial P_{Ak}} = \frac{(2-\Omega)P_{Ak} + P_{kl}}{P_{Ak}} = 2 - \Omega + \frac{P_{kl}}{P_{Ak}} \tag{34}$$

Substitute A_k into equation (23) and the real economic cost is：

$$\begin{aligned}W &= A_k \times P_{Ak} + X \times (1-\Omega) + \sum_k \sum_l A_k \times P_{kl} \\ &= X \times (\frac{P_{Ak}}{P_{kl}} + 2 - \Omega) \geq 2X \sqrt{\frac{P_{Ak}}{P_{kl}} \times (2-\Omega)}\end{aligned} \tag{35}$$

At this time, the cost-benefit ratio can not only reach the best, but also the damaged environment can be improved sufficiently. The decision maker of the company should decide the size of the occupied area A_k according to the actual situation required by the project to achieve the win-win goal of the company's interests and environmental and ecological protection.

3. Cost of environmental protection > Cost of environmental degradation

The cost of environmental protection invested by the company is greater than the cost of environmental degradation, thus better protecting the environment. In this case, the environment is more effectively managed. Since the cost of environmental protection cannot be fully compensated for the cost of environmental degradation, meanwhile, the utilization rate of environmental cost decreases gradually with time, and the protection effect is significantly reduced. Only with increased investment will it be possible to protect as much of the degraded environment as possible.

To sum up, company decision makers should improve the environment to preserve energy, reduce the number of the amount of harmful emissions for the proposed environmental protection measures, invest higher environmental protection cost than environmental degradation cost and select the project area reasonably to guarantee the company profit under less environmental damage according to its own actual situation.

4.5 Cumulative environmental degradation costs in relation to time.

In the process of project construction or the construction has been completed, with the passage of time, the model has some problems in the evaluation of environmental protection costs.

1. Environmental degradation has a certain degree of irreversibility or a decline in governance effects. The model is a step-by-step process in the process of protecting the environment. As time goes by, the treatment effect of some environmental factors is degraded or irreversible, that is, the environmental protection cannot be used to achieve environmental recovery. For example, in the process of investing certain environmental protection costs to protect the atmosphere from pollution, the compensation coefficient of ecosystem service value in the model is reduced by logarithmic function over time, and the invested capital may not all be effective. As a result, the air quality suddenly becomes better. However, only a part of the environmental protection costs invested can reach the intended purpose.

According to the formula, the true environmental protection cost is shown as follows:

$$X(1-\Omega)=X(1-\frac{1}{\ln T}) \tag{36}$$

Then it is concluded that the benefit of environmental protection cost acting on environmental degradation cost is as follows:

$$X\Omega=\frac{X}{\ln T} \tag{37}$$

2.Environmental degradation has accumulated to a certain extent and may cause certain natural disasters such as earthquakes and droughts. Among the environmental protection costs invested, the effect of environmental protection is gradually declining, the environmental deterioration is intensified, and the cumulative amount is a certain degree. The quantitative change causes qualitative changes, and it is very likely that extreme phenomena such as natural disasters will occur. For example, in the process of construction of the company, the degree of deterioration of the environment is intensified, causing earthquakes, and the entire model will be greatly affected. Over time, the cost of environmental protection in the model is no longer applicable to extreme conditions. The model should consider extreme conditions and invest more environmental protection costs to protect the environment.

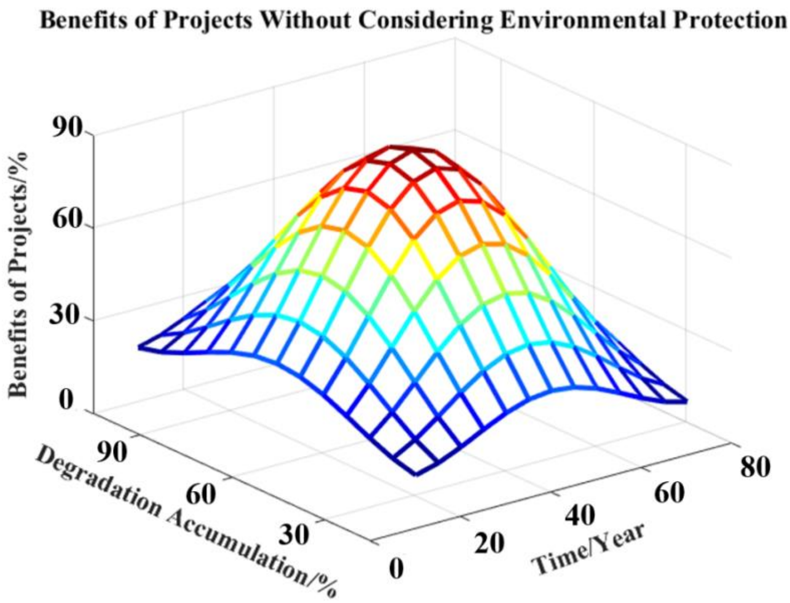

Figure 3: The cumulative relationship between project benefits and time and environmental degradation

As shown in equations (17) and (21), if the model invests all of the investment in the construction cost, the environmental protection cost is invested regardless of environmental degradation. As time goes by, the benefit of the land project increases with the cost of investment and construction. Increased; however, the ability of environmental degradation is still intensifying, reaching a certain threshold, and the benefits begin to decline sharply, which will have a serious impact on the company.

5. Advantages and disadvantages of the model

5.1 Advantages of the model

1. In the process of establishing the task 1 model, in order to make the model more realistic, we considered various factors related to the project and the ecological environment, such as environmental degradation costs, environmental protection costs and construction costs, and related to environmental protection costs. A number of protection indicators, such as saving energy consumption, reducing emissions of harmful substances, reducing the loss of materials, etc., the results of derivation and calculation are more realistic.

2. The task 1 model replaces most of the indicators with a few important indicators in advance, and uses the principal component analysis method to select the six most

important indicators occupying the main components of the ecosystem, such as climate regulation, from 17 indicators related to ecosystem services. Water conservation, soil formation, etc.

5.2 shortcomings of the model

1. A certain amount of big data is missing to verify the validity of the model.
2. The construction cost considerations of land use projects are not comprehensive enough and ideal.

6. Model improvement

1. In the answer to Task One, we need to acquire more economic knowledge and economic models to optimize our cost calculations, and consider adding other cost calculations related to ecosystem services to the model, such as the environment. Governance costs, etc. In addition, we need to find and collect more factors related to environmental protection costs to make the compensation coefficient of ecosystem service value in the model more realistic.
2. In the answer to Task 2, we need to review and sort out more factors that affect the size of the project, such as the construction area, the value of different types of construction.
3. In the answer to Task 3, we need to collect more accurate data to verify the robustness of the model, such as whether the model can use different types of large and small projects based on different countries.

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Appendix

Appendix 1: Average Value of Global Annual Ecosystem Services

Biological Communities	Area	Ecosystem Services																	Total value per hectare (USD/ha/year)	Total Global Traffic Value (USD)
		Atmosphere Adjustment	Climate Regulation	Interference Adjustment	Water Regulation	The Water Supply	Erosion Control	Soil Formation	Nutrient Cycling	Waste Disposal	Pollination	Biological Control	Habitat/Shelter	Food Production	The Raw Materials	Genetic Resources	Recreation	Culture		
Ocean	36302																		577	20949
The High Seas	33200	38							118			5		15	0			76	252	8381
The Coast	3102			88					3677			38	8	93	4		82	62	4052	12568
The Gulf	180			567					21100			78	131	521	25		381	29	22832	4110

Seaweed	200								19002						2				19004	3801
Coral Reefs	62			2750								5	7	220	27		3008	1	6075	375
The Continental Shelf	2660								1431	58		39		68	2			70	1610	4283
Land	15323																		804	12319
The Forest	4855		141	2	2	3	96	10	361	87		2		43	138	16	66	2	969	4706
A Tropical Rainforest	1900		223	5	6	8	245	10	922	87				32	315	41	112	2	2007	3813
Temperate/Coniferous Forests	2955		88		0			10		87		4		50	25		36	2	302	894
Grassland/Pasture	3898	7	0		3		29	1		87	25	23		67		0	2		232	906
Wetland	330	133		4539	15	3800				4177			304	256	106		574	881	14785	4879
Tidal Marsh/Mangrove	165			1839						6696			169	466	162		658		9990	1648

Swamp/Flood Plain	165	265		7240	30	7600				1659			439	47	49		491	1761	19580	3231
Lakes/Rivers	200				5445	2117				665				41			230		8498	1700
Desert	1925																			
Tundra	743																			
Ice/Rock	1640																			
Arable Land	1400										14	24		54					92	128
The City	332																			
Total	51625	1341	684	1779	1115	1692	576	153	17075	2277	117	417	124	1386	721	79	815	31015		33268

Appendix 2: Principal Component Analysis (PCA) MATLAB codes

```
dataset   = xlsread('Data.xlsx');
data      = zscore(dataset);
r         = corrcoef(data);

[vec1, lamda, rate] = pcacov(r)
f = repmat(sign(sum(vec1)), size(vec1, 1), 1);

vec2 = vec1 .* f
num = 4;
df  = data*vec2(:, 1:num);
tf  = df * rate(1:num)/100;
[stf, ind] = sort(tf, 'descend');
stf = stf'
ind = ind'
```

Appendix 3: Material Loss Ecological Cost

Material	Ecological Cost RMB/kg
Aluminum	17.51
Concrete	0.21
Cement	0.31
Cement Mortar	0.25
Asphalt	6.75
Rubber（EPDM）	10.76
Polystyrene Foam Board（PS, EPS）	3.94
Polystyrene Foam Board（XPS）	14.31
Solvent-based Alkyd Coatings（White）	25.76
Solvent-based Acrylic Paint（White）	16.52
Acrylic Varnish (Transparent)	2.14
Adhesive Glue	2.65
Gypsum	0.03
Glass	1.77
Glass Wool	2.92
Gravel	0.05
Lime-sand Brick	0.19
Brick of Pottery and Porcelain	0.34
Copper	22.27
Lead	5.59
Zinc	16.71
PE Plastic	8.74
PP Plastic	8.70
PVC Plastic	5.79
Steel Girder, Steel Plate, Steel Pipe	5.81
Reinforced	6.64
Steel	4.91
Welding Electrode	100.76
Acetylene	3.84
Asbestos	2.52
ABS Resin	10.88
Sand	0.02
Wood Plywood	1.24
Bamboo Plywood	2.77

Appendix 4: Material Recovery Theory

Material	Regeneration Rate α (%)	Reuse Rate β (%)	Comprehensive Recovery Rate γ (%)
Aluminum	94	0	94
Concrete	60	0	60
Asphalt	5	0	5
Rubber (EPDM)	5	0	5
Polystyrene Foam (PS,EPS,XPS)	5	0	5
Other Polymer Materials	5	0	5
Ceramic	80	5	85
Gypsum	5	0	5
Glass	70	0	70
Glass Wool	10	0	10
Gravel	0	90	90
Brick	99	0	99
Wood	10	5	15
Lime-sand Brick	99	0	99
Copper	85	0	85
Lead	95	0	95
Zinc	95	0	95
Other Metals	90	0	90
PE, PP Plastic	5	0	5
PVC Plastic	70	0	70
Steel Plate, Steel Pipe	87	12	99
Steel	51	49	100
Reinforced	94	0	94
Asbestos	10	0	10
Resin	20	0	20
Sand	0	99	99

Notice: Calculated according to the table in the recycle utilization of the material loss ecological cost is in fully recycling and reuse of ideally corresponding ecological cost, but in real life, considering the actual level of recycling society cannot reach the ideal state, so the material loss of ecological cost will be higher than the theoretical value.

Appendix 5: Environmental Protection Costs of Hazardous Emissions

Emissions	Environmental protection cost（$/kg）	Emissions	Environmental protection cost（$/kg）
CO_2	0.135	VOC	3.54
CO	0.15	C_2H_4	5.74
SO_2	8.25	CH_4	3.78
PO_4^-	11.82	$PM_{2.5}$	34.00
NO_x	5.67	PM_{10}	20.40
N_2O	5.67	Dust	5.34

Appendix6: Gasoline and Diesel Prices and Ecological Costs

Kind	Calorific Value (MJ/kg)	Density (kg/L)
Gasoline	43.070	0.725
Diesel	42.652	0.840
Fuel Ethanol	30.33	0.789
Biodiesel	38.00	0.840

Appendix 7: Data of ecological environmental pollution in China from 2004 to 2013

Project Year			Unit	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Material Object Accounting	Water	Waste Water	100 million tons	607.2	651.3	723.9	769.2	807.2	847.9	873.2	874	925	929.5
		COD	100 million tons	2109.3	2195	2345	2223	2765	2847	3021	2480	2405	2330
		Ammonia Nitrogen	100 million tons	223.2	242.5	248.3	241.7	200.5	208.6	216.4	256.1	251.7	243.6
	Atmosphere	SO_2	100 million tons	2450.2	2568.5	2680.6	2434.3	2323.5	2148.2	2090.8	2217.1	2117.4	2043.7
		Smoke Dust	100 million tons	2000.6	2093.7	2705.6	2384.1	2071.5	1895.1	1277.9	1215.7	1171.9	1218.6
		NOX	100 million tons	1646.6	1937.1	2173.2	2374.6	2494.1	2631	2796.1	2403.9	2337.4	2226.6
	Solid Waste	General Industrial Solid Waste	100 million tons	27428.5	27108.2	23701.1	25311.7	22469.5	21420	24418.2	42688.4	59930	42764
		Hazardous Wastes	100 million	344.4	337.9	286.8	154.01	196.21	218.91	167.81	918.73	846.91	810.88

			tons										
		Household Waste	100 million tons	6667.5	6029.6	7896.1	6927.4	6116.8	6300.4	7173.4	7175.5	7062.3	8245.7
Governance Cost	Actual Governance Cost	Waste Water	100 million RMB	344.4	400.7	562	653.7	786.2	1083.2	1298.1	1232.6	1619.4	1560.2
		Exhaust Gas	100 million RMB	478.2	835	1046.2	1369.7	1775.9	1923.7	2204.8	3148.4	3102.8	3150.1
		Solid Waste	100 million RMB	182.7	217.3	195.1	281.9	340.8	330.5	414.7	601	579.6	611.7
		Total	100 million RMB	1005.3	1453	1803.4	2305.3	2902.9	3337.4	3917.5	4982	5301.7	5322
	Virtual Governance Cost	Waste Water	100 million RMB	1808.7	2084	2143.8	2121.1	2613.5	2993.8	3490.1	2203.4	2097.1	1979.6
		Exhaust Gas	100 million RMB	922.3	1610.9	1821.5	2104.8	2227.7	2343.3	1952.9	4197.1	4464.4	4704.8
		Solid Waste	100 million RMB	143.5	148.7	147.3	129.8	142.9	133.8	146.3	325.6	326.7	288.9
		Total	100 million RMB	2874.4	3843.7	4112.6	4355.6	4984	5470.8	5589.3	6726.2	6888.2	6973.3

Environmental Degradation Cost	Water	100 million RMB	2862.8	2836	3387	3595.1	4105	4310.9	4620.4	5644.2	6064.9	6752.1
	Exhaust Gas	100 million RMB	2198	2869	3051	3616.7	4725.6	5197.6	6183.4	6683.8	6750	8611
	Solid Waste	100 million RMB	6.5	29.6	29.6	65.1	63.6	136.6	168	274.2	457.3	308.1
	Contamination Accident	100 million RMB	50.9	53.4	40.2	57.2	53.3	56	61	88.2	85	123.3
	Total	100 million RMB	5118.2	5787.9	6507.7	7334.1	8947.6	970101	11031.8	12690.4	13357.6	15794.5
GDP	Total Industry	trillion	15.99	18.31	21.09	24.59	30,07	36.4	40.12	52.14	51.89	56.88
	Subtotal of Regions	trillion	16.76	19.78	23.11	27.56	32.72	36.53	43.7	52.14	57.66	63
Pollution deduction index	Total Industry	%	1.8	2.1	2	1.7	1.7	1.5	1.4	1.4	1.8	1.2
	Subtotal of Regions	%	1.72	1.94	1.78	1.58	1.54	1.5	1.3	1.3	1.8	1.1
Environmental Degradation Index		%	3.05	2.93	2.82	2.66	2,73	2.66	2.52	2.43	2.3	2.5
Ecological Damage Loss		100 million RMB	/	/	/	/	3961.8	4206.5	4417	4758.5	4745.9	4753.5
Cost of Environmental Degradation		100	/	/	/	/	1274	1391	1551	1744	1810	2054

	million RMB					5.7	6.2	3.8	9	3.5	7.9
Index of Ecological and Environmental Degradation	%	/	/	/	/	3.9	3.8	3.5	3.3	3.1	3.3

Appendix 8: China regional accounting results in 2013

district / Project		GDP/100 million	Virtual governance cost/100 million	Pollution deduction index/%	environmental degradation cost/100 million	Environmental degradation index/%	Ecological damage loss/100 million	Ecological damage index(%)	Cost of environmental damage/100 million	Ecological environment destruction index (%)
Eastern Region	Beijing	19500.6	164.8	0.8	391.8	2.01	5.8	0.03	397.6	2.04
	Tianjin	14370.2	92.2	0.6	346.2	2.41	8.4	0.06	354.6	2.47
	Hebei	28301.4	401.1	1.4	1774.2	6.27	107	0.38	1881.2	6.65
	Liaoning	27077.7	258	1	582	2.15	109.9	0.41	692	2.56
	Shanghai	21602.1	95.6	0.4	519.8	2.41	7	0.03	526.8	2.44
	Jiangsu	59161.8	606.8	1	1248.7	2.11	75.2	0.13	1323.9	2.24
	Zhejiang	37568.5	522.2	1.4	721.3	1.92	92	0.24	813.3	2.16
	Fujian	21759.6	154.7	0.7	348.6	1.6	18.4	0.08	367	1.68
	Shandong	54684.3	557.5	1	1543.1	2.82	149.7	0.27	1692.8	3.09
	Guangdong	62164	476.1	0.8	973.9	1.57	136.1	0.22	1110	1.79

	Hainan	3146.5	29.7	0.9	40.4	1.28	10.1	0.32	50.5	1.6
	sub-total	349336.5	3359.5	0.96	8490	2.43	719.5	0.21	9209.6	2.64
	Of the country than	55.4	48.2		54.1		15.1		45	
Centrale Region	Hainan	12602.2	207.4	1.6	368.9	2.93	266.6	2.12	635.5	5.05
	Jilin	12981.5	133.2	1	262	2.02	92.3	0.71	354.3	2.73
	Heilongjiang	14382.9	198.6	1.4	377.4	2.62	480.8	3.34	858.2	5.96
	Anhui	19038.9	222.7	1.2	437.1	2.3	35.1	0.18	472.2	2.48
	Jiangxi	14338.5	152.3	1.1	248.7	1.73	35.5	0.25	284.2	1.98
	Henan	32155.9	384.6	1.2	985.8	3.07	162	0.5	1147.8	3.57
	Hubei	24668.5	251.8	1	395.2	1.6	182.7	0.74	577.9	2.34
	Hunan	24501.7	208.7	0.9	605.5	2.47	166.8	0.68	772.3	3.15
	sub-total	154670	1759.3	1.14	3680.6	2.38	1421.7	0.92	5102.3	3.3
	Of the country than	24.6	25.2		23.4		29.9		24.9	
Western region	Hunan	16832.4	185.8	1.1	509.1	3.02	489.7	2.91	998.8	5.93
	Guangxi	14378	159.6	1.1	258.2	1.8	177.8	1.24	436	3.04

	Chongqing	12656.7	125.7	1	368.7	2.91	6.2	0.05	374.9	2.96
	Sichuan	26260.8	308.8	1.2	520.8	2.02	239.1	0.91	769.9	2.93
	Guizhou	8006.8	108.7	1.4	300.1	3.75	74.2	0.93	374.3	4.68
	Yunnan	11720.9	182.4	1.6	232.5	1.98	150.8	1.29	383.3	3.27
	Tibet	807.7	57.7	7.1	43.5	5.38	474.2	58.71	517.6	64.09
	Shaanxi	16045.2	202.8	1.3	516.8	3.22	99.6	0.62	616.4	3.84
	Gansu	6268	114	1.8	259.5	4.14	203	3.24	462.5	7.38
	Qinghai	2101.1	113.7	5.4	84.6	4.03	507	24.13	591.6	28.16
	Ningxia	2565.1	74.8	2.9	152.6	5.95	26	1.01	178.6	6.96
	Xinjiang	8360.2	220.5	2.6	275.9	3.3	164.7	1.97	440.6	5.27
	total	1260028.8	1854.5	1.5	3532.4	2.8	2612.2	2.07	6144.6	4.87
	Of the country than	20	26.6		22.5		55		30	
	all	6300093.3	6973.3	1.1	15794.5	2.51	4753.5	0.75	20547.9	3.3