Establishment and Application of Ecological Cost Estimation Model

Jiaqing Zhang[1, a]

[1]School of Jiaqing zhang, North China Electric Power University, Beijing, China.

[a]1287050235@qq.com

Abstract

It is one-sided to simply analyze land development projects with economic theories, because the ecological cost of the projects is not taken into account. In order to quantify the ecological cost, we established an ecosystem service evaluation model. In order to quantify the impact of engineering on the environment, we establish a life cycle assessment model. It is based on the calculation of the amount of damage to the environment caused by the three factors and indirectly obtains the ecological cost. The three aspects are: harmful emissions brought by the project, the use of modern primary energy and the non-recyclability of engineering materials. However, because the above three indicators are only evident in large and long-term projects, they are less practical for small projects. For this reason, we introduce entropy weight evaluation model. It is a model reflecting environmental quality by calculating the information entropy change and entropy flow of 14 index data of ecosystem service types after range standardization, which is easy to calculate for small projects. Since both the life cycle assessment model and the entropy weighting assessment model can reflect the changes of the environment, we used the statistical data of China from 2008 to 2017 to obtain the ecological cost and entropy flow value of each year, and tested the correlation between them. The correlation coefficient was -0.85, so they have a strong correlation. Then the data points in matlab to simulate the smooth curve. Then the corresponding ecological cost can be found on the curve through the entropy flow value. At the same time, we also analyzed the sensitivity and effectiveness in the paper. Our model can assess the environmental costs of both large national and small community projects. At the same time, we also analyze the advantages and disadvantages of our model. In addition, the modification method of the model with time variation is given. If the model can be generalized, then the planners and managers of land-use projects can be more aware of the huge environmental costs. For example, China's GDP in 2017 was $34.33 trillion, while the environmental costs were calculated to be $26.93 trillion. Accounting for 78% of GDP. This will serve as a reminder of how much damage has been done to the environment in the wake of the cold economic growth figures.

Keywords

Entropy weighting evaluation model, life cycle evaluation model, information entropy, entropy flow, ecological cost.

1. Introduction

1.1. Background

In order to meet the increasing demand for resources, people are developing and utilizing more and more land. However, the development of land destroys water resources, vegetation and air, which is worsening the ecological environment. According to statistics, about 27375 species of animals are extinct every year, and the air quality is deteriorating year by year. People's living environment is not optimistic. These phenomena are reminding people that cost analysis of land development and utilization should not be limited to economic costs, but also pay attention to environmental costs. Therefore, it is necessary to establish a model to quantitatively evaluate the environmental cost of the project. The calculation of environmental costs is difficult, because the impact of land development projects on the environment often takes a period of time to show, and the impact is not a single project.

1.2. Exposition and Analysis of Problems

At present, most project cost estimates only consider economic costs, not environmental costs. Therefore, the evaluation of the value of a project is inaccurate. We hope that we can evaluate the comprehensive value of a project through a quantitative model. At the same time, large-scale and small-scale projects differ greatly, and the existing models are difficult to analyze the two at the same time. Therefore, we need to establish a model that can evaluate both the value of small projects and the comprehensive evaluation of national-level projects. Type. For the whole model, if we want to get the cost of ecological degradation more accurately and reasonably, the key part is how to quantify the cost with mathematical model. First, we need to judge the sustainability of ecosystem services used by the project and quantify them in the form of indicators, so as to judge whether the impact of the project on Ecosystem services is positive or negative. The model makes the cost of ecological degradation applicable to the calculation method of market economy, which makes it more convenient for project managers to carry out cost budget and project management. Finally, this mathematical model can also adjust the future changes of the project, and still can get more accurate results.

Through the above analysis, the flow chart of this paper is shown in fig.1 as follows.

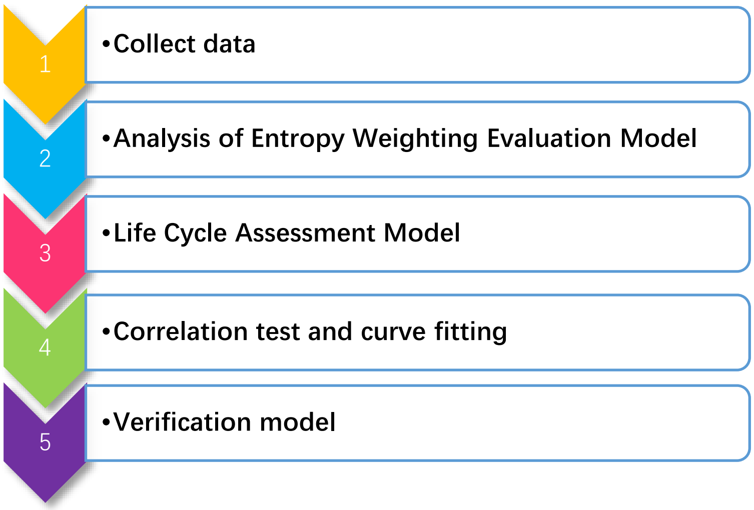

Fig 1

2. Establishment of Entropy Weighting Evaluation Model

2.1. Determination of Evaluation Index

The model takes the regulation and supply of services provided by two ecosystems as a reference, and the transformation of human behavior to nature as a breakthrough point to construct an evaluation model of entropy value empowerment. It simplifies the process of interaction between the two, taking the expression of human activity intensity and the measurement of ecosystem service potential as the main factors, and only considers them as the "source" of ecosystem service flow (initial supply). Giving area) and "sink" (final demand area). Therefore, the ecosystem service flows of different spatial supply-demand relations, different functions, different sources and sinks are classified into three categories. As follows:

1. The supply of ecosystem resources needed for human survival: the natural ecosystem of a city is a process of increasing entropy, which produces positive entropy flow and is a negative indicator. Sources and sinks are natural ecosystems and human needs in turn.

2. Human actions to maintain the stability of natural ecosystem: the natural ecosystem of a city is a process of entropy reduction, and negative entropy flow is a positive indicator. Sources and sinks are in turn human needs and natural ecosystems.

3. Internal regulation of natural ecosystem: including human and non-human behavior. Generally, it includes both the process of increasing and decreasing entropy. Natural ecosystems are both sources and sinks, such as natural succession of forests. It is difficult to accurately describe each part of the service flow. Therefore, relative variation values are considered to describe the sum of their internal comprehensive effects. [1] The change of land cover and land type is the most important factor affecting ecosystem service function [2]. Different cover reflects the regulation information of climate, pollution and water flow. Different land use also provides food and water supply services. [3] The area of land type in this paper represents the attributes of land cover (e.g. the area of garden green space at the end of the year) to produce. The number of products produced represents land use attributes (e.g. grain yield, etc.). In addition, typical human activities which have strong impact on the urban natural ecosystem are selected to join the evaluation model, such as water resources, energy consumption and air pollution shared by the three major industries in the process of urban development; active and harmless treatment is adopted after a large amount of garbage and sewage are produced. Finally, the index evaluation model is constructed. Although different land use patterns are different, the index system in this paper is relatively comprehensive and has reference value for the evaluation of the ecological situation of large and small projects, because it considers the impact of different projects on the ecological environment and the common consumption of natural ecosystem resources of land by the population with a certain base in order to survive.

2.2. Entropy and Urban Ecosystem Services

The principles for calculating the entropy flow of land ecosystem services are as follows: when the system is in a non-equilibrium state, the service flow represented by various indicators is different or the stability degree of the system and the outside is different, the gradient will be generated between different parts of the system or between the system and the outside world, and the entropy flow will be generated by the exchange of energy through the pro-gradient or anti-gradient. For an open system, entropy generally consists of two parts: the system always evolves spontaneously toward the direction of increasing entropy, i.e. more disorderly, so one part is due to the increase of entropy caused by irreversible factors within the system, forming a positive entropy flow; the other part is the entropy flow generated in the process of exchanging matter and energy with the outside world as an open system, which can be positive or negative, and its value depends on all of them. The total effect of the exchange process. In most cases, it is difficult to monitor and quantify the specific process of entropy increment in the system, and the internal positive entropy flow has the same effect on the system as the positive entropy flow generated by the exchange between the system and the external energy [4]. Therefore, the two kinds of entropy flow are merged.

Finally, the entropy flow calculation of urban ecosystem can be expressed as:

$$dS=dSn+dSp \tag{1}$$

Where dS is the total entropy flow for systems;

dSn is the sum of positive entropy flow generated for the energy exchange between the system and the outside world and the internal entropy of the system;

dSp is the sum of negative entropy flows for energy exchange between system and external environment.

When dS > 0, the system is in the state of increasing entropy, with excessive accumulation of negative factors, and the system is developing in an unhealthy direction.

When dS < 0, the system is in the state of entropy reduction, and there are many positive factors accumulated. The system is developing in an orderly and positive direction.

When dS = 0, the system is in equilibrium.

Information entropy is one of the measures to express the difference between different parts of the system or between different parts of the system and the equilibrium point. It is a measure of the degree of uncertainty expressed by probability. The larger the information entropy is, the more disorderly the system is. The determinate urban ecosystem means the worse the ecological environment, and the system information entropy is calculated as follows:

1) Firstly, the original matrix An×m of each year index is constructed.

2) In order to avoid the loss of practical significance in comparing the indexes of different order of magnitude of cardinality, the range standardization of the original matrix An×m is carried out. The calculation method is as follows:

$$b_{ij} = \frac{b_{ij}^{*} - b_{j,min}}{b_{j,max} - b_{j,min}} \tag{2}$$

Where b_{ij}^{*} is the jth index value of the first year in the initial matrix;

$b_{j,max}$ is the optimum value of the J index in n years;

$b_{j,min}$ is the minimum value of J index since n years.

For positive indicators beneficial to the ecological environment, the optimal value is the maximum, whereas the optimal value is the minimum.

3) The calculation method of information entropy (S_j) of the jth index is as follows:

$$S_j = -\frac{1}{\ln n} \sum_{i=1}^{n} \frac{b_{ij}^{*}}{b_j} ln \frac{b_{ij}^{*}}{b_j} \tag{3}$$

Where $b_j = \sum_{i=1}^{n} b_{ij}^{*}$ is the sum of the jth index for all years.

4) Generally speaking, the expert scoring method is used to assign the weights of various indicators. Generally, there are subjective interference components in this method. Therefore, the entropy weight method is used to weigh the indicators. The calculation formula is as follows:

$$W_j = \frac{1 - S_j}{m - \sum_{j=1}^{m} S_J} \tag{4}$$

Where m is the number of indicators for ecosystem services.

5) According to the nature of two kinds of ecosystem service flows, the entropy flows generated by different service flows are classified into positive and negative categories. Negative entropy flows are obtained by taking the opposite number on the basis of the corresponding weight of

the indicators and multiplying the information entropy values of the indicators. All positive and negative entropy flows are added to get the total entropy flows of the system.

2.3. Construction of Evaluation Matrix of Urban Ecosystem Service Flow in Beijing Based on Entropy Theory

According to the existing urban ecosystem service assessment model, 14 indicators from 2008 to 2017 were selected to construct the evaluation model of ecosystem service flow in China.

Table 1

			2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Regulatory services	Forest coverage	10^4 hm^2	2.076873	2.0769	2.0769	2.0769	2.0769	2.0769	2.076873	2.0769	2.0769	1.9545
	Garden green space area at the end of the year	10 hm^2	4.446	4.169	3.838	3.524	3.298	3.062	2.858	2.582	2.358	2.183
	Construction land area	10^2 hm^2	5.515547	5.27613	5.15841	4.998274	4.71085	4.575067	4.186061	3.975842	3.872692	3.914046
	Overall mileage of roads in China	10^8 m	3.98	3.82	3.65	3.52	3.36	3.27	3.09	2.94	2.69	2.6
	Garden area	10^6 hm^2	7.524125	7.2151	7.1736	7.066	6.9127	6.68648	6.53413	6.32339	6.11587	5.86659
	Total water resources	10^{13} hm3	2.87612	3.24664	2.79626	2.72669	2.795786	2.952879	2.32567	3.090641	2.41802	2.74343
Supply service	Total Energy Consumption	10^9 tce	4.49	4.3581863	4.29905	4.25806	4.16913	4.02138	3.87043	3.60648	3.36126	3.20611
	Harmless rate of garbage	%	97.7	96.6	94.1	91.8	89.3	84.8	79.7	77.9	71.4	66.8
	Relative value of standing stock	10^{10} hm^3	1.6433	1.6433	1.6433	1.6433	1.6433	1.6433	1.6433	1.6433	1.6433	1.3618
	Main crop yields	10^8 t	6.616072	6.604352	6.606027	6.396483	6.30482	6.122262	5.884933	5.591131	5.394086	5.343429
	Dry and Fresh Fruit Product Yield	10^8 t	2.52419	2.440524	2.452462	2.330263	2.27481	2.20915	2.101861	2.009537	1.909371	1.810875
	Production of animal husbandry agricultural products	10^7 t	8.65443	8.62833	8.74952	8.8179	8.63277	8.4711	8.02298	7.99361	7.70667	7.37088
	Total annual water supply	10^6 t	593.76	580.69	560.47	546.66	537.3	523.03	513.42	507.87	496.75	500.08
	Total amount of motor vehicles	10^8	2.090667	1.857454	1.628445	1.459811	1.267014	1.093309	0.935632	0.780183	0.628061	0.509961

2.4. Computation Flow

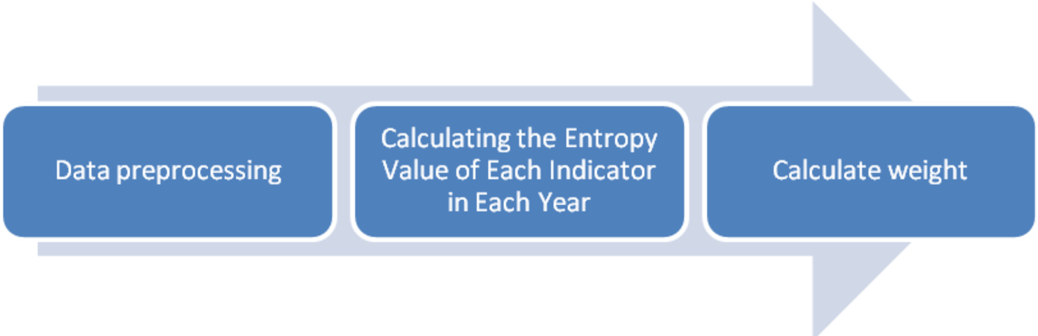

Fig.2

1. Data preprocessing: In order to avoid the impact of the magnitude of indicators on the results, data preprocessing should be carried out. Min-max standardization is adopted to make the data fall between 0 and 1. The calculation method is as follows:

$$x^* = \frac{x - min}{max - min} \tag{5}$$

The standardized results are as follows:

Table 2

		2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Regulatory services	Forest coverage	0.046209151	0.046209752	0.046209752	0.046209752	0.046209752	0.046209752	0.046209151	0.046209752	0.046209752	0.043483562
	Garden green space area at the end of the year	5.04033E-05	4.42338E-05	3.68615E-05	2.98678E-05	2.48342E-05	1.95778E-05	1.50341E-05	8.88685E-06	3.89774E-06	0
	Construction land area	0.001179845	0.00112652	0.001100301	0.001064634	0.001000617	0.000970374	0.000883731	0.00083691	0.000813935	0.000823146
	Overall mileage of roads in China	4.00242E-05	3.64606E-05	3.26742E-05	2.97787E-05	2.62151E-05	2.42105E-05	2.02014E-05	1.68605E-05	1.12923E-05	9.28776E-06
	Garden area	0.016133457	0.016021425	0.015928993	0.015689337	0.015347895	0.01484404	0.014504714	0.014035337	0.013573132	0.013017916
	Total water resources	0.064010618	0.072263135	0.062231912	0.060682394	0.062221355	0.065720255	0.051750556	0.068788601	0.053807449	0.06105524
Supply service	Total Energy Consumption	1	0.970641401	0.957470093	0.948340473	0.928533274	0.895625215	0.862004427	0.803215377	0.748598022	0.714041776
	Harmless rate of garbage	0.000168984	0.000166534	0.000160966	0.000155843	0.000150275	0.000140252	0.000128893	0.000124884	0.000110406	0.000100161
	Relative value of standing stock	0.000317387	0.000317387	0.000317387	0.000317387	0.000317387	0.000317387	0.000317387	0.000317387	0.000317387	0.000254689
	Main crop yields	0.147309812	0.147048775	0.147086082	0.142418951	0.14037736	0.136311282	0.131025301	0.124481509	0.120092765	0.118964492
	Dry and Fresh Fruit Product Yield	0.056172152	0.054308676	0.054574569	0.051852855	0.050617762	0.04915533	0.046765704	0.04470939	0.042478413	0.040284631
	Production of animal husbandry agricultural products	0.019227215	0.019169083	0.019439007	0.019591309	0.019178973	0.018818888	0.0178208	0.017755384	0.017116289	0.01636839
	Total annual water supply	0.001273848	0.001244738	0.001199702	0.001168943	0.001148096	0.001116313	0.001094908	0.001082547	0.00105778	0.001065197
	Total amount of motor vehicles	0.046516382	0.041322076	0.036221405	0.032465454	0.028171325	0.024302429	0.020790521	0.017328237	0.013940054	0.011309637

2. Calculate the entropy of each index for each year.
3. Calculating weights.
4. Computing Entropy Flow with Weight and Entropy Value.
5. The calculation results are as follows.

Table 3

		2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
	Forest coverage	0.046209151	0.046209752	0.04620975	0.046209752	0.0462098	0.04620975	0.046209151	0.04620975	0.046209752	0.043483562
	Garden green space area at the end of the year	5.04033E-05	4.42338E-05	3.6861E-05	2.98678E-05	2.483E-05	1.9578E-05	1.50341E-05	8.8868E-06	3.89774E-06	1.00E-06
Regulatory services	Construction land area	0.001179845	0.00112652	0.0011003	0.001064634	0.0010006	0.00097037	0.000883731	0.00083691	0.000813935	0.000823146
	Overall mileage of roads in China	4.00242E-05	3.64606E-05	3.2674E-05	2.97787E-05	2.622E-05	2.4211E-05	2.02014E-05	1.6861E-05	1.12923E-05	9.28776E-06
	Garden area	0.016133457	0.016021425	0.01592899	0.015689337	0.0153479	0.01484404	0.014504714	0.01403534	0.013573132	0.013017916
	Total water resources	0.064010618	0.072263135	0.06223191	0.060682394	0.0622214	0.06572026	0.051750556	0.0687886	0.053807449	0.06105524
	Entropy change	0.444847876	0.433966716	0.4446105	0.444741106	0.4407139	0.43425582	0.446200926	0.42520505	0.438766596	0.428875475
	weight	0.04199227	0.04277677	0.0419999	0.0419696	0.0332925	0.0427099	0.0418325	0.0433549	0.0423786	0.0430905
	Entropy flow	0.018680172	0.018563694	0.0186736	0.018665606	0.0146725	0.01854702	0.0186657	0.01843472	0.018594314	0.018480459
	Total Energy Consumption	1	0.970641401	0.95747009	0.948340473	0.9285333	0.89562521	0.862004427	0.80321538	0.748598022	0.714041776
	Harmless rate of garbage	0.000168984	0.000166534	0.00016097	0.000155843	0.0001503	0.00014025	0.000128893	0.00012488	0.000110406	0.000100161
	Relative value of standing stock	0.000317387	0.000317387	0.00031739	0.000317387	0.0003174	0.00031739	0.000317387	0.00031739	0.000317387	0.000254689
	Main crop yields	0.147309812	0.147048775	0.14708608	0.142418951	0.1403774	0.13631128	0.131025301	0.12448151	0.120092765	0.118964492
Supply service	Dry and Fresh Fruit Product Yield	0.056172152	0.054308676	0.05457457	0.051852855	0.0506178	0.04915533	0.046765704	0.04470939	0.042478413	0.040284631
	Production of animal husbandry agricultural products	0.019227215	0.019169083	0.01943901	0.019591309	0.019179	0.01881889	0.0178208	0.01775538	0.017116289	0.01636839
	Total annual water supply	0.001273848	0.001244738	0.0011997	0.001168943	0.0011481	0.00111631	0.001094908	0.00108255	0.00105778	0.001065197
	Total amount of motor vehicles	0.046516382	0.041322076	0.0362214	0.032465454	0.0281713	0.02430243	0.020790521	0.01732824	0.013940054	0.011309637
	Entropy change	0.334811104	0.333773197	0.33182076	0.32523445	0.3216728	0.31954909	0.315302834	0.31691002	0.31790495	0.317058579
	weight	0.050315563	0.050348678	0.05052942	0.0510026	0.0512424	0.0513695	0.05172016	0.0515233	0.0515048	0.0515169
	Entropy flow	0.016846209	0.016805039	0.01676671	0.016587803	0.0164833	0.01641508	0.016307513	0.01632825	0.016373631	0.016333875
	Total Entropy Change (Regulating Service + Supply Service)	0.77965898	0.767739913	0.77643126	0.769975556	0.7623867	0.75380492	0.76150376	0.74211506	0.756671546	0.745934054
	Total weight	0.016667	0.0175526	0.0169068	0.017386547	0.0179499	0.018586	0.01801536	0.01945144	0.01837367	0.0191689
	Entropy flow	0.012994576	0.013475832	0.01312697	0.013387216	0.0136848	0.01401022	0.013718764	0.01443521	0.013902833	0.014298735

3. Life Cycle Assessment Model

In order to calculate the environmental cost in ecosystem services, the life cycle model proposed by Ran Ran et al. in The Study on Environmental Cost and EVR Model of Construction Process [5] was introduced to analyze the environmental cost.

3.1. Concept Introduction

3.1.1. Definition of Life Cycle Assessment

To quote Liang Chen et al., GB/T 24040-2008 Environmental Management- Life Cycle Assessment- Principles and Framework National Standard Understanding. Life cycle assessment (LCA) considers the entire life cycle of a product, from acquisition of raw materials to final disposal.LCA concerned about the environment factors and impact on the environment, considering the environment, and resources of all attributes or factors, is built around functional unit has a relative method, and is a kind of repeated use of a method of other results environmental cost is one of life cycle assessment index, is used to land development used to quantify the cost of ecological degradation.

3.1.2. Definition of Ecological Cost

Hendriks[7] proposed a single indicator based on life cycle assessment, which can be used to evaluate the sustainability of products or activities. Voigtlander [8] proposed that the ecological cost includes the sum of three marginal costs, namely, the ecological cost of hazardous emission, the ecological cost of renewable energy instead of primary energy, and the non-recyclable cost of materials. But it's important to note that ecological costs are a class of virtual costs.

Environmental cost consists of three parts: harmful emissions, energy and ecological cost and material unrecoverable cost, as it shown in fig.3 [9].

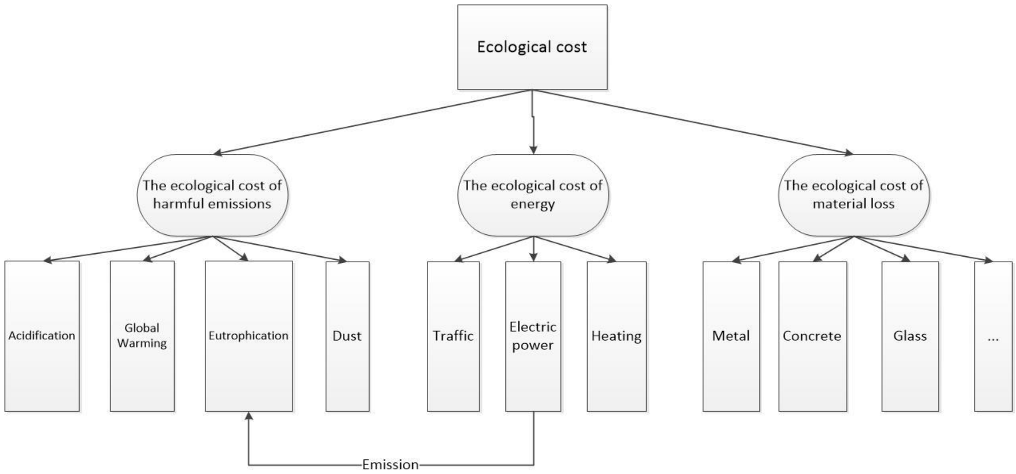

Fig 3

3.2. Environmental Cost Calculation of Projects

3.2.1. Environmental Costs of Hazardous Emissions

The environmental cost of harmful emissions is the sum of the individual environmental costs [10] of each harmful emission, and the individual environmental cost is equal to the highest unit cost of the emission reduction measures adopted.

$$P_m = \max\{C_i\} \ (i=1,2,\ldots,n) \tag{6}$$

where Pm is the individual environmental costs of harmful emissions;

Ci is the unit cost of emission reduction measures.

The following table shows the individual environmental cost data of harmful emissions in the EU.

Table 4

Environmental costs	CO_2	CO	SO_2	NO_x
€/kg	0.134	0.246	7.45	5.30
￥/kg	1.045	1.856	58.11	40.82
$/kg	0.15	0.29	8.65	6.14

Note: According to the exchange rate of Euro to RMB on January 27, 2019: 1€=7.6972￥, 1€=1.1412$.

Because the emission of harmful emissions cannot be counted, the environmental cost of harmful emissions can be obtained by equivalent calculation of primary energy consumption. Table 5 lists the relationship table between harmful emissions and energy consumption when energy is used. By conversion, the environmental cost of harmful emissions can be obtained:

$$C_e = \sum_{i=1}^{n}(Y_i \times Q_i \times D_{mi}) \tag{7}$$

where Ce is the environmental costs of harmful emissions from energy;

Yi is the type i harmful emissions from energy;

Qi is the emissions of class i harmful substances per unit energy;

Dmi is the environmental costs of harmful emissions type i.

Table 5

	CO_2	CO	SO_2	No_x
Gasoline(g/MJ)	12.66	588	441.8	298
Diesel(g/MJ)	12.51	580	438.6	295
Coal(g/MJ)	16.2	0.3365	0.143	654.2
CNG(g/MJ)	3.341	415	273	685

Table 6 lists the environmental costs of harmful emissions from fossil fuels from 2008 to 2017.

Table 6

	Unit																				
Year		2017		2016		2015		2014		2013		2012		2011		2010		2009		2008	
Gas species		CO2	CO	CO2	CO	CO2	CO	CO2	CO	CO2	CO	CO2	CO	CO2	CO	CO2	CO	CO2	CO	CO2	CO
Gasoline	10^{11}g	6.639951	310.85	6.2355	291.92	6.154	288.1	5.2922	247.76	5.0702	237.36	4.4069	206.31	4.0036	187.43	3.7277	174.51	3.3414	156.43	3.3267	155.74
Diesel	10^{11}g	11.07134	504.45	10.71	487.98	9.9965	455.48	9.8842	450.36	9.8758	449.98	9.7695	445.13	9.0031	410.21	8.4265	383.94	7.9214	360.93	7.7924	355.05
Coal	10^{11}g	211.347	4.3704	201.97	4.1765	180.09	3.724	186.71	3.8609	192.52	3.9811	159.96	3.3078	155.56	3.2169	141.63	2.9288	134.19	2.7749	127.51	2.6367
CNG	10^{11}g	0.021752	2.6447	0.0201	2.4467	0.0179	2.1755	0.0173	2.1048	0.0158	1.9206	0.0136	1.6476	0.0121	1.47	0.0099	1.2044	0.0083	1.0082	0.0075	0.9155
Cost	Trillion dollars	0.003529	0.0225	0.0034	0.0215	0.003	0.0205	0.0031	0.0193	0.0032	0.019	0.0027	0.018	0.0026	0.0165	0.0024	0.0154	0.0022	0.0143	0.0021	0.0141
Year		2017		2016		2015		2014		2013		2012		2011		2010		2009		2008	
Gas species		SO2	Nox	SO2	Nox	SO2	Nox	SO2	Nox	SO2	Nox	SO2	Nox	SO2	Nox	SO2	Nox	SO2	Nox	SO2	Nox
Gasoline	10^{11}g	233.4556	157.01	219.23	147.45	216.37	145.52	186.07	125.14	178.27	119.89	154.94	104.21	140.76	94.671	131.06	88.146	117.48	79.013	116.96	78.665
Diesel	10^{11}g	388.1607	261.07	375.49	252.55	350.48	235.73	346.54	233.08	346.24	232.88	342.52	230.38	315.65	212.3	295.43	198.71	277.72	186.8	273.2	183.75
Coal	10^{11}g	1.735133	8534.8	1.6581	8156.1	1.4785	7272.3	1.5328	7539.8	1.5806	7774.5	1.3133	6459.6	1.2771	6282	1.1628	5719.4	1.1017	5419	1.0468	5149
CNG	10^{11}g	1.7827	4.4731	1.6493	4.1382	1.4665	3.6796	1.4188	3.56	1.2946	3.2484	1.1106	2.7867	0.9909	2.4863	0.8118	2.037	0.6796	1.7052	0.6171	1.5485
Cost	Trillion dollars	0.538619	5.4075	0.5153	5.1678	0.4909	4.6227	0.4614	4.7701	0.4544	4.9083	0.4307	4.1033	0.3952	3.9792	0.3692	3.6272	0.342	3.4329	0.3376	3.2678
Total cost	Trillion dollars	5.972162426		5.707938661		5.137144998		5.253964577		5.384915627		4.554687891		4.393541867		4.014138171		3.791452187		3.621608441	

3.2.2. Environmental Costs of Energy

The environmental cost of energy is to replace the general energy used in the project with renewable energy. Table 7 calculates the ecological costs of each energy source.

Table 7

Types of energy	Value ($/MJ)	Major sustainable energy sources	Ecological costs ($/MJ)
Gasoline	0.023727	Fuel ethanol	0.034108
Diesel	0.020762	biodiesel	0.017796
Coal	0.002966	Biomass corn stalk fuel	0.005931
CNG	0.081	Biomass corn stalk fuel	0.005932
Electric energy	0.008898	Hydropower + wind energy + biomass + photovoltaic + ocean energy + geothermal energy	0.0163213

The environmental cost of energy can be calculated by knowing the proportion and cost of various renewable energy sources. The formula is as follows:

$$C_{de} = \sum_{i=1}^{n}(M_i \times D_i) \quad (8)$$

Where Cde is 0.016$/MJ;

M_i is the generation cost of renewable energy;

D_i is the corresponding power generation ratio.

3.2.3. Non-Recoverable Cost of Materials

When calculating the non-recyclable cost of materials, because raw materials are recyclable, such as crude steel, glass and so on, the impact of recycling rate on ecological cost should also be considered in the analysis of ecological cost of this part. The concrete calculation formula is as follows:

$$C_u = C_o \times (1-r) \tag{9}$$

Where Cu is the non-recoverable cost of materials;

Co is the cost of raw materials and r is the rate of recovery.

We refer to the recovery rate of materials in several literatures and summarize them in Table 8 [11-13]. We also refer to the unit price and quantity of various materials and summarize the environmental cost of each material in Table 9 [14].Table 8

Table 8

Materials	Crude steel	Crude aluminum	Glass	Concrete
Recovery (%)	62.67	80	11.7	2

Table 9

Year		2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Materials											
Crude steel	Weight (10kt)	70447	70940	70035	74038	76575	68761	66793	61206	56206	50206
	Unit price ($/10kt)	5399899.6	5226240.3	4970719.4	4694940.72	4488432.97	4397717.86	4301441.5	4223064.95	4080415.18	3643701.34
	nvironmental costs(Trillion dollars	0.142018511	0.138413142	0.129966418	0.129772168	0.128315322	0.112892818	0.107260975	0.096498048	0.085621691	0.068295983
Crude aluminum	Weight (10kt)	3329	3264.5	3141	2885.8	2543.8	2314.1	1961.4	1577.1	1288.6	1316.5
	Unit price ($/10kt)	19976010	18656140	17336270	15839923	14597169	14481495	13987656	13696988	13548688	13246156
	nvironmental costs(Trillion dollars	0.013300027	0.012180594	0.010890645	0.00914217	0.007426456	0.006702326	0.005487078	0.004320304	0.003491768	0.003487713
Glass	Weight (10kt/PCS)	83765.8	80408.4	78651.6	83128.2	79285.8	75050.5	79107.6	66330.8	58574.1	59890.4
	Unit price ($/10kt)	1468170	1447704.6	1429908.6	1397430.9	1369698.8	1337814.3	1269744.6	1249130.9	1204640.9	1181209.5
	nvironmental costs(Trillion dollars	0.10859349	0.10278792	0.099306241	0.102574503	0.095891738	0.088656407	0.088694214	0.073161717	0.062305148	0.062466166
Concrete	Weight (10kt)	233084.1	241031	235918.8	249207.1	241923.9	220984.1	209925.9	188191.2	164397.8	142355.7
	Unit price ($/10kt)	4152400	3856600.82	3642248	3316729.5	3144568.03	2966177.96	2962233.18	2854775	2558175	2258609
	nvironmental costs(Trillion dollars	0.948501249	0.910969145	0.842089282	0.810021489	0.745531238	0.642368604	0.609412477	0.526498662	0.412147175	0.315095348

4. Correlation Analysis and Fitting

4.1. Test of Correlation

The correlation test tool is used to test the correlation between entropy flow and ecological cost, and the correlation between entropy flow and ecological cost is -0.85005. It is believed that they have a strong correlation, and a curve fitting can be conducted for them.

4.2. The fitting of Entropy Flow and Ecological Cost

By analyzing the ten-year data of China, the curve describing the relationship between entropy flow and ecological cost was obtained and fitted with matlab. CFTOOL tool and smooth spline were used to fit the curve in Matlab.

Table 10

	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Entropy flow	0.012995	0.013476	0.013127	0.013387	0.013685	0.01401	0.013719	0.014435	0.013903	0.014299
Ecological cost	26.93401	25.73929	23.33379	23.56964	23.76453	20.24806	19.48064	17.67227	16.36303	15.3734

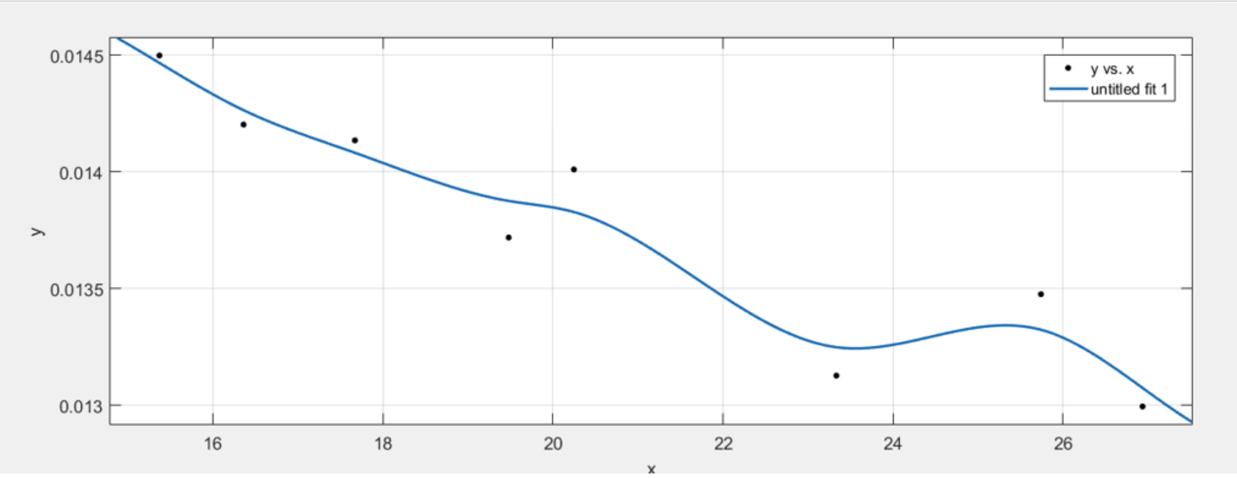

Fig 4

5. Validity Assessment

Table 11 shows the ecological cost of the shanty town reconstruction project in Huangxi village, Shijingshan district, Beijing in 2014.

Table 11

			Year: 2014	standardization
Regulating services	Forest coverage	10^4 hm^2	58.81	0.005603968
	Garden green space area at the end of the year	10 hm^2	2.23	0.000137201
	Construction land area	10^2 hm^2	15.68	0.001436741
	Overall mileage of roads in China	10^8 m	0.81	0.0003
	Garden area	10^6 hm^2	240.5	0.023158879
	Total water resources	10^{13} hm3	20.3	0.001883126
	comentropy			0.02767
	weight			0.071721
	entropy flow			0.00198452
Supply service	Total Energy Consumption	10^9 tce	4972.84	0.480398191
	Harmless rate of garbage	%	99	0.009487131
	Relative value of standing stock	10^{10} hm^3	8.15	0.000709192
	Main crop yields	10^8 t	10350.62	0.98
	Dry and Fresh Fruit Product Yield	10^8 t	263.49	0.025380176
	Production of animal husbandry agricultural products	10^7 t	84.3	0.008066815
	Total annual water supply	10^6 t	22.65	0.002110184
	Total amount of motor vehicles	10^8	907.71	0.087624797
	comentropy			0.415221
	weight			0.04313
	entropy flow			0.017908482
	the total entropy flow			0.019893

By the total entropy flow of 0.019893 on the entropy flow - fitting curves of environment cost find corresponding environmental cost 0.1069 trillions of dollars.

Table 12

gasoline	Ten thousand tons of	112.66129
diesel	Ten thousand tons of	92.2688774
coal	Ten thousand tons of	469.326192
gas tax	Million Cubic Meters	23.306905
gasoline	MJ	528658484
diesel	MJ	138999778
coal	MJ	9859925544
gas tax	MJ	653003
environmental costs of harmful emissions	trillions of dollars	
CO2		0.0354
SO2		0.0289
CO2		0.0008
Nox		0.0217
total		0.0868
Energy and environmental costs	trillions of dollars	
gasoline		0.002657
diesel		0.002547
coal		0.001589
gas tax		0.001425
electric energy		0.002482
total		0.0107
Non-recyclable environmental material cost	trillions of dollars	
Crude Steel		0.00375
Primary Aluminum		0.00261
sheet glass		0.001589
Cement		0.008551
total		0.011
Total environmental cost	trillions of dollars	0.1085

Then, the environmental cost of 0.1085 trillion U.S. dollars is calculated from three aspects by life cycle assessment model, which is not much different from the fitting value of 0.1069 trillion U.S. dollars. It is considered that the model is effective.

6. Conclusion

The fitting of the information entropy flow of ecosystem services and the environmental cost calculated by the weighted evaluation model of the entropy value can evaluate the environmental cost of land use development projects. After verifying the correlation between entropy flow and environmental cost, the validity of this model is proved, that is, complex environmental cost can be estimated by easily calculated entropy flow.

Through our model, the planners and managers of land development projects can clearly realize that the ecological costs caused by environmental degradation are enormous. Whether waste emissions, harmful gases emissions, modern energy and material non-recyclability will bring about environmental degradation, that is, the information entropy of ecosystem will change, and then need to pay the corresponding costs. Economic cost. That is to say, the cost-benefit ratio will change, that is to say, we need to add the final environmental cost in our model, in order to get a true and effective cost-benefit ratio.

7. Strength and Weakness

7.1. Strength

The applicability of the model is strong: Whether large-scale national projects or small-scale regional projects, as long as the entropic flow of the project is calculated by the entropic value weighting model, the corresponding ecological costs can be queried through the curve fitting between the two.

The model is simple to use: many of the 14 parameters need to be calculated in the process of Engineering design, so the cost of obtaining information is low.

7.2. Weakness

The fitting curve is not accurate enough: because this model only chooses 10 years' data to fit, the discrete points are less, so the fitting curve may not be accurate enough.

8. Improvement of the Mode

Over time, the applicability of the model will deteriorate and need to be revised.

Firstly, the change of the entropy flow model is small, because the correlation parameters change little with time. However, the parameters of life cycle assessment model will change obviously with time. Specific analysis is as follows: The first part of the cost, along with environmental changes, the ecological value of each pollutant will also change. This part of the change needs to be based on the statistical decision of marginal cost of harmful pollutant emissions, which can be quoted from the statistics of EU and other institutions. In the second part of the cost, as the technology is updated and iterated, the environmental cost of generating energy will also change. It is gratifying that we can meet this change towards a more environmentally friendly direction. The third part of the cost, the ecological cost of building materials, will also be reduced with the emergence of new high recovery materials.

Therefore, in order to make the model more applicable, the above cost should be revised regularly in order to obtain more accurate curve.

References

[1] Jingxin Li, Li Yang, Lei Yang, Chao Zhang, Zhaomin Huo, Minhao Chen, Xiaofeng Luan. Quantitative assessment of urban ecosystem services flow based on entropy theory: A case [J].Chinese Journal of Applied Ecology, Mar. 2018, 29(3):987-996.

[2] Burkhard B, Kroll F,Nedkov S,et al.Mapping supply, demand and budgets of ecosystem services[J].Ecological Indicators, 2012(21):17-29.

[3] Grafius DR,Warren PH,Hancock S.The impact of land use/land cover scale on modelling urban ecosystem services[J].Landscape Ecology, 2016(31):1509-1522.

[4] Song YJ. Ecological city and urban sustainable development. Procedia Engineering, 2011,21: 142–146.

[5] Ran Ran, Lei Zheng. Eco-costs and Eco-costs/Value Ratio in Construction Process[J].Journal of Engineering Management, Jun 2016, 30(3).

[6] Liang Chen, Mei Liu, Jin Huang. GB/T 24040-2008 Environmental Management- Life Cycle Assessment- Principles and Framework National Standard Understanding[J].China National Institute of Standardization, 2009(2).

[7] Hendriks C F, Voigtländer J. The eco-costs/value-ratio [J]. Sustainable city ii: urban regeneration and sustainability. 2002. 559.

[8] Voigtländer J G, BIJMA A. The ‘Virtual Pullution Prevention Costs’99[J]. Int J Life Cycle Assess, 2000, 5(2): 113-120

[9] ISO 14040, Life Cycle Assessment- Principles and Framework. Geneva: International Organization for Standardization, 1997.

[10] Ning Ding, Jianxin Yang.Life cycle inventory analysis of fossil fuels in China[J].China Environmental Science, 2015, 35(5):1592-600.

[11] Xing Su, Xu Zhang, Yongqiang Sun.Material life cycle inventory analysis model considering recycling capacity[J].Journal of Tongji University (NATURAL SCIENCE EDITION), 2011, 10(10):1528-1530,1547.

[12] Wei Lu.Waste Recycling System Material Metabolism Analysis Model and Its Application[D].Tsinghua University, 2010.

[13] Cheng Guan, Zibo Jiang, Songyuan He.Status analysis and development prospect of China plastics recycling industry[J].Plastics, 2009, 38(3):36-38.

[14] National Bureau of Statistics (NBS). http://www.stats.gov.cn/