Multi-index Cost-benefit Model to Assess Land Development Costs

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Abstract. In land development and utilization projects, managers rarely consider the loss of ecosystem service value, often resulting in waste of resources. Based on the land development and utilization project, this paper proposes a multi-indicator cost-benefit comprehensive analysis model (MCCAM). MCCAM divides the four aspects of the indicator system by dichotomy, including determining resource loss costs through MESV, calculating environmental degradation costs using delay factors, considering project planning factors and market fluctuations, and correcting economic benefits and costs. On the other hand, MCCAM quantifies the value of the ecosystem service value model and combines the non-equalized cobweb model with time-delay effects to modify the model parameters. According to the sensitivity analysis of the model, this model provides effective suggestions for the planning and management personnel of the land development and utilization project.

1. Introduction

As we all know, the biosphere provides many natural resources for human life to maintain a healthy and sustainable environment. These are called ecosystem service systems. However, whenever humans change ecosystems, people may limit or eliminate the repair function of ecosystem services. But in this era of rapid economic development, project developers often overlook many of the project's impact on the biosphere. It is hoped that an assessment model based on ecosystem service capabilities will be established, while considering the environmental costs in the assessment model to understand its true economic costs.

Cost-benefit analysis is a method of assessing the value of a project by comparing the full cost and benefit of the project. Cost-benefit analysis is an economic decision-making method that applies cost-benefit analysis to the planning decisions of government departments to seek. How to get the most benefit from investment decisions with minimal cost often used to assess the value of public utility projects that need to quantify social benefits.

The cobweb theory, also known as the cobweb model, uses the elasticity theory to examine the dynamic analysis of the impact of price volatility on the yield of the next cycle. It is a theoretical model used for market equilibrium state analysis. The cobweb theory is one that emerged in the 1930s. A method of dynamic equilibrium analysis.

Although the multi-indicator model has many advantages, it is suitable for project analysis and decision making. The multi-indicator model also has shortcomings such as parameters that cannot be updated according to actual conditions and not time-sensitive. In this paper, the cobweb model and...
delay factor are integrated into the multi-indicator model, which innovatively solves the shortcomings of the multi-indicator model.

This paper has the following main contributions:
(1) Establish a multi-indicator cost-benefit comprehensive analysis model (MCCAM);
(2) Determine the cost of resource loss through the MESV;
(3) Added delay factor and time delay effect model to MCCAM;
(4) Modify the MCCAM parameters through the spider model.

2. Methodology
For the land development and utilization project, this paper divides the four aspects of the evaluation index system by the dichotomy, including the resource loss cost determined by the MESV, the delay factor to calculate the environmental degradation cost, the project planning factors and market fluctuation factors, and the correction of economic benefits and costs. Based on the above four aspects, this paper establishes a multi-indicator-based cost-benefit analysis model (MCCAM) and applies it to cost-benefit analysis from small community projects to large-scale national projects. Then, we verify the validity of the model from the perspective of sensitivity analysis. According to the above model and marginal utility theory, effective suggestions are made for the planning and management personnel of the land development and utilization project. Over time, we introduce a dynamic value equivalence factor and establish a non-equilibrium cobweb model with a time-delay effect to modify the model. This paper comprehensively analyzes the advantages and disadvantages of the model by reducing the complexity of the whole process of project evaluation and the synergistic destruction of the project.

Figure 1. Model creation flow chart.
3. Cost-benefit Comprehensive Analysis Model Based on Multiple Indexes

3.1. Assessment of ecosystem service value
Ecosystem and its ecological process continuously provide ecosystem goods and services to human beings, thus forming and maintaining the environmental conditions and material basis for human survival. The process is the embodiment of ecosystem services. We believe that ecosystem services are of super high value and are closely related to human well-being and destiny [6]. Therefore, we evaluate ecosystem services from the perspective of ecosystem service value. Our model’s idea is as follows:

![Diagram](image)

**Figure 2.** The Idea Diagram of Establishing MESV Model.

3.2. Determine the value of ecosystem services per unit area.
Current research on ecosystem services focuses on terrestrial ecosystems, which include forests, grasslands, farmland, wetlands, water bodies and deserts [7].

In order to eliminate the impact of price fluctuations of ecosystem services on the total value of ecosystem services, we use the services provided by forest ecosystems as an example to demonstrate. Based on the area corresponding to the main service types in the M mountain forest ecosystem, the service supply per hectare system, and the annual average price of services provided by the mountain, we calculate the services provided by the M mountain forest ecosystem. The economic value is about 388.379 (dollar / hectare), our calculation model is as follows:

$$ E_s = \delta \sum_{i=1}^{m} \frac{S_i P_i q_i}{M} \quad i=1,2,L,m $$

We use the distribution area of ecosystem types and ecosystem service value coefficient to determine ESV [8]

$$ ESV = \sum_{i=1}^{m} \sum_{j=1}^{n} V C_{ij} \cdot A_j $$

3.3. Correcting ESV based on biomass factors and socio-economic factors
(1) Analysis of model research status
The current ecosystem service value calculation models are mostly based on the value of the services provided by the ecosystem. Therefore, the ESV model is highly objective and lacks consideration of the collaborative development between the ecosystem and human beings. In order to
fully consider the effects of human activities and geographical differentiation in the ESV model, we added biomass and socioeconomic factor adjustment coefficients to the model. And correct the traditional ESV model by adding adjustment factors [14].

2) Biomass factor adjustment

Based on the linear correlation between biomass and ecosystem service value, we adjusted biomass factors by comparing Net Primary Productivity (NPP) of vegetation in different regions. First, we apply Thornthwaite Memoria model to the calculation of net primary productivity of vegetation [15]. Next, we use the average temperature and annual precipitation to reflect the actual annual evapotranspiration and annual average evapotranspiration in the region, and calculate the net primary productivity of the vegetation in the study area. The calculation process is as follows:

STEP 1: Establish a model of net primary productivity NPP for vegetation in the study area.

\[
NPP = 3000[1 - \exp(-0.00097(V - 20))]
\]

\[
V = \frac{1.05AP}{\sqrt{1 + (1 + 1.05AP / L)}}
\]

\[
L = 0.05AAP^2 + 25AAP + 3000
\]

STEP 2: The net primary productivity of vegetation was calculated for each country and region. Here, NPP_g and NPP_s of the national net primary productivity of vegetation are obtained. By using Arcmap10.5 to calculate the meteorological data of the research area and combining the national meteorological data and the meteorological data of the research area.

STEP 3: Calculate the biomass factor adjustment factor S:

\[
S = \frac{NPP_s}{NPP_g}
\]

(3) Adjustment of socio-economic factors

We try to measure the coefficient of Socio-economic factor adjustment coefficient from two aspects: the coefficient of willingness to pay and the coefficient of ability to pay.

STEP 1: Based on qualitative analysis, a quantitative analysis is conducted on the parameter W of people's willingness to pay.

\[
W = \frac{2}{1 + \exp(2.5 - \frac{1}{En})}
\]

STEP 2: According to the Engel coefficient of the study area and the country, the study parameters and the willing parameters of the people of the country Ws and Wg are calculated. We calculate two WTP by calculating the willingness coefficient of the people in the study area:

\[
W_t = \frac{W_s}{W_g}
\]

STEP 3: Based on qualitative analysis, people's payment capacity coefficient At is quantitatively analyzed:

\[
A_t = \frac{GDPe_{research\_area}}{GDPe_{world}}
\]
STEP 4: The adjustment coefficient $PI$ of social and economic factors was calculated.

$$PI = W_i \cdot A_i$$

(9)

(4) Establish a modified ESV model based on adjustment coefficient of biomass factor and adjustment coefficient of socio-economic factor.

$$MESV = \sum_i (A_i \cdot VC_i \cdot S \cdot PI) \quad (i = 1, 2, L, n)$$

(10)

4. Evaluation and Grading Model based on projection pursuit

4.1. Selection of data indicators and evaluation levels

Based on the ESV model above, we continue to follow the relevant specifications for forest ecosystems [10]. Among the indicators used in the above model, indicators related to ecosystem services are selected, including: water resources, forest area, wetland area, grassland area, annual precipitation, energy consumption, and natural disaster losses. The grading standards for evaluation indicators at all levels are shown in Table 1.

### Table 1. Ecosystem Service Value Rating Form.

| Class | Class I | Class II | Class III | Class IV | Class V |
|-------|---------|----------|-----------|----------|---------|
| $\sigma_1$ | $>$1000 | 800-1000 | 500-800 | 200-500 | $<$200 |
| $\sigma_2$ | $>$1500 | 600-1500 | 300-600 | 100-300 | $<$100 |
| $\sigma_3$ | $>$3000 | 1000-3000 | 300-1000 | 50-300 | $<$50 |
| $\sigma_4$ | $>$20000 | 5000-20000 | 1000-5000 | 500-1000 | $<$500 |
| $\sigma_5$ | $>$1500 | 1000-1500 | 500-1000 | 200-500 | $<$200 |
| $\sigma_6$ | $>$15000 | 12000-15000 | 8000-12000 | 3000-8000 | $<$3000 |
| $\sigma_7$ | $>$3000 | 1000-3000 | 500-1000 | 100-500 | $<$100 |

4.2. Establish PPE model based on RAGA rating standard

(1) Normalization and standardization of sample data

First, we integrated the collected data into a $5 \times 7$ matrix, and then normalized and standardized the sample matrix, as follows:

$$x(i, j) = \frac{x'(i, j) - \bar{x}'(j)}{S_{x'(j)}}$$

(11)

(2) The projection index function is constructed and optimized

Firstly, based on the known index sample value $x$, we determine the optimal projection direction by constructing a maximal programming problem about the $p$-dimensional projection index, and obtain the following nonlinear optimization model as follows:
Next, we imported the planning model into MATLAB2014b and applied RAGA for solving. We selected the initial total group size of the parent generation $n=100$, crossover probability $PC=0.80$, mutation probability $PM=0.80$, number of excellent individuals selected as 20, $a=0.05$, acceleration times as 4, and obtained the optimal projection direction as $\mathbf{a} = (0.736, 0.254, 0, 0.57, 0.264)$. For this level of ecosystem service value of standard sample projection value $= [2.879, 1.011, 0.342, 2.254, 1.264]$ (as shown in the figure below).

\[
\begin{align*}
\max : Q(a) &= S_z D_z \\
z(i) &= \sum_{j=1}^{n} a(j) \cdot x(i, j) \\
r(i, j) &= |z(i) - z(j)| \\
S_z &= \sqrt{\frac{\sum_{i=1}^{n} (z(i) - \bar{z}(i))^2}{n - 1}} \\
D_z &= \sum_{i=1}^{n} \sum_{j=1}^{n} (R - r(i, j)) \cdot (R - r(i, j)) \\
i &= 1, 2, \ldots, n \\
\sum_{j=1}^{n} a^2(j) &= 1
\end{align*}
\tag{12}
\]

Figure 3. Ecosystem Service Value Comprehensive Evaluation Level Map.

4.2.1. PPE model evaluation and conclusions. We combine the projection values with the five regions we collected for analysis, and use the method of the standard data processing in the previous section to perform a series of identical processing on the sample data, and finally comprehensively evaluate them and select them. Set the respective evaluation levels, and then get the evaluation results as shown below:

Table 2. Grade evaluation results of sample areas.

|          | Area A | Area B | Area C | Area D | Area E |
|----------|--------|--------|--------|--------|--------|
| Sample sequence | Class III | Class II | Class V | Class III | Class I |
4.3. Constructing an indicator system for comprehensive analysis models

4.3.1. Resource and environmental cost. For one thing, the cost of resource loss is mainly reflected in the value of ecosystem services lost during land development. Therefore, we use MESV to represent it. For another, the cost of environmental degradation refers to the total cost of the human or material resources that the government or other relevant departments pay for environmental protection within a certain period of time. Thus, we calculate the cost of environmental degradation and then use it to represent the cost of resources and environment:

\[ B_{ev} = MESV + B_j \]  

(13)

\[ B_j = \sum_{k=1}^{m} EL_k \times (1 - R_k) \times P_k \]  

(14)

4.3.2. Total project cost. We calculate the economic cost of the project respectively through the deterministic formula of the project cost. On the basis of it, we introduce market volatility factors to quantify the impact of market economy on the economic cost of projects, so as to improve the synergy between land use and development projects and market economy, which reduces the lag caused by indicators in the cost calculation process.

In order to fully consider the external effects of land use projects, we analyze and demonstrate the exponential growth theory and Logistic retardation theory [12].

\[ MESV = \exp(-a \cdot COST + b) \]  

(15)

4.4. Comprehensive project evaluation based on dynamic assessment indicators

Through the MESV model and the econometric decision model, we determined the total cost and total return of the land development project. After that, we introduce the concept of net present value, internal rate of return, and cost-benefit ratio in economic theory. Combine with the model to improve and analyze the project cost and benefit. The specific analysis process is as follows:

(1) Economic Net Present Value

It refers to the sum of the present value of the project's annual net economic benefit flow discounted to the initial stage of construction in accordance with the social discount rate, calculated as follows:

\[ ENPV = \sum_{t=1}^{n} (B - C)_t (1 + i_s)^{-t} \]  

(16)

(2) Economic Internal Rate of Return (EIRR)

It refers to the discount rate when the current value of the economic benefit flow of the project is equal to 0 in the calculation period, which is calculated as follows:

\[ \sum_{t=1}^{n} (B - C)_t (1 + EIRR)^{-t} = 0 \]  

(17)

(3) Economic benefit cost ratio (RBC)

It refers to the ratio of the present value of the benefit flow of the project during the calculation period to the present value of the expense flow, calculated as follows:
If the RBC is greater than 1, it indicates that the economic efficiency of project resource allocation has reached an acceptable level.

4.5. Advice to management
We use the cost-benefit analysis model combined with the law of diminishing marginal effects in economic theory to make reasonable and effective recommendations to project plan managers. In order to unify the starting point of the model application of the cost-benefit analysis model, we introduce a land development degree indicator and analyze the cost and benefit of the land development and utilization project based on the degree of land development. We determine that the land development degree is greater when the ecosystem land area is constant. That is, the larger the land development project area, the greater the project cost and project income. The logical relationship between the two is in line with the economic theory.

\[
R_{BC} = \frac{\sum_{t=1}^{n} B_t (1 + i_t)^{-t}}{\sum_{t=1}^{n} C (1 + i_t)^{-t}} \tag{18}
\]

The above formula shows that when the marginal cost of construction land expansion is equal to the marginal benefit, the land expansion benefit of land development can reach the maximum value. At the same time, the difference between total cost and total income is maximized to maximize project profit (The profitability during the expansion process is shown in the figure).

\[
\begin{align*}
\frac{dP}{dLc} &= B'(Lc) - C'(Lc) = 0 \\
B'(Lc) &= C'(Lc) \tag{19}
\end{align*}
\]

By analyzing the profitability of the project during the land expansion process, we propose the following points to the project planning and management personnel based on the cost-benefit analysis model:

1) The land development limit can be effectively determined. When the development marginal benefit is equal to the marginal cost, the development project benefit rate is maximized;

2) The actual benefits of the project can be determined. In actual land development projects, most developers do not consider the damage to the value of ecosystem services, which can be calculated
through the cost-benefit model we have established. Opportunity costs of ecosystem services resulting from development projects;

(3) Choosing the optimal development project. The benefits and costs brought by different projects are different. Through the model, the actual benefits of each cost can be calculated to select the project with the maximum benefit.

5. Model application and inspection

5.1. Cost-benefit assessment of small development projects
We used the previously established cost-benefit model for the evaluation of the land development project to analysis the F region. For the static cost of the project:

**Table 3. Static cost table in Area F.**

| Project                   | Value ($10^8$ dollars) | %   |
|---------------------------|------------------------|-----|
| Land Expropriation        | 0.62                   | 16.76|
| Pre-engineering           | 1.34                   | 36.22|
| Infrastructure Investment | 1.20                   | 32.43|
| Indirect Development      | 0.54                   | 14.59|
| **Total**                 | **3.70**               | **100.0**|

According to the regular expression of value, we calculate the cost of the project that is $4.02 \times 10^8$ dollars. The total cost of the project calculated by the formula (4.13), which is $4.16 \times 10^8$ dollars. Secondly, the project's income statement is as follows:

**Table 4. Project income table in Area F.**

| Project                | Value ($10^8$ dollars) | %   |
|------------------------|------------------------|-----|
| Community Woodland     | 0.45                   | 9.30|
| Non-wood               | 0.07                   | 1.45|
| Wood                   | 1.12                   | 23.14|
| Crop Income            | 3.20                   | 66.12|
| **Total**              | **4.84**               | **100.0**|

Finally, based on the above two tables, we have obtained the net income, cost-benefit ratio and internal income of the land development project.

**Table 5. NPV, RBC and IRR for land development projects in Area F.**

| Project                                | Discount Rate | Discount Rate | Discount Rate | Discount Rate | NPV   | RBC   | IRR(%) |
|----------------------------------------|---------------|---------------|---------------|---------------|-------|-------|--------|
| Excluding cost of previous grazing     | 0.03          | 0.05          | 0.03          | 0.05          | 1.75  | 1.23  | 17.0   |
| (a)                                     |               |               | 1.92          | 1.67          |       |       |        |
| Including cost of previous grazing     |               |               | 1.7           | 1.79          | 1.69  | 14.8  |        |
| (a)                                     |               |               |               |               |       |       |        |

From the above table, it can be concluded that in both cases, the benefit-cost ratio of the F Zone is 1.23 and 1.19. Respectively, it indicates that the economic efficiency of project resource allocation has reached an acceptable level.
5.2. Cost and benefit assessment of national land development projects

For national-level land development projects, we believe that large projects of this type should be macro planning based on the overall situation of the country. Based on the collected land project development data of various regions in China and the above Cost-benefit Evaluation Model, we obtain the land development degree of various regions in China, as shown in the figure:

![Statistical map of land development breadth and utilization rate in Chinese provinces](image)

**Figure 5.** Statistical map of land development breadth and utilization rate in Chinese provinces.

5.3. Effectiveness analysis from the perspective of sensitivity

To determine the validity of the model, we performed a sensitivity analysis of the model. Sensitivity analysis refers to the identification of sensitive factors that have important influence on the project economic benefit indicators among many uncertain factors in the process of economic evaluation. In the meanwhile, it analyzes and measures the degree of influence and sensitivity of the project economic benefit indicators. Analytical methods. The specific analysis steps are as follows:

1. Determine the research object of sensitivity analysis.
2. Select uncertain factors in the analysis.
3. Calculate and analyze the influence degree of variable factors on the benefit index of the investment project.
4. Prepare sensitivity analysis table and find out the sensitivity factors.
5. Calculation of sensitivity coefficient and critical point.

Sensitivity coefficient is used to express the sensitivity of project evaluation index to uncertain factors, and the calculation formula is as follows:

\[
E = \frac{\Delta A}{\Delta F}
\]  

(20)

6. Clear sensitivity factors. The ultimate point at which the sensitivity factor may change the most (even when the benefit index value of the project starts to become unfeasible from feasible) is called the maximum limit value.

Taking the project development in the F Area as an example. By consulting the relevant materials, we obtained the economic evaluation index table of the project as shown in the figure. We analyze the sensitivity and cost of the sensitivity analysis, and finally get the sensitivity analysis indicator table as shown below:
Table 6. Economic evaluation index table.

| CNPV ($10^8$ dollars) | the ratio of benefit and cost | IRR |
|------------------------|------------------------------|-----|
| 10.98                  | 1.92                         | 17  |

Table 7. Summary table of sensitivity analysis indexes.

| project                             | CNP ($10^8$ dollars) | the ratio of benefit and cost | IRR  |
|-------------------------------------|----------------------|------------------------------|------|
| Cost increase by 10%                | 10.69                | 1.83                         | 15.65|
| Reduced efficiency by 10%          | 8.51                 | 1.81                         | 15.8 |

### 6. Conclusion

This paper selects the key six indicators through the analysis of indicators, and then establishes a corresponding multi-index cost-benefit analysis model. In this paper, some indicators are added to the MESV model index system to characterize environmental degradation and human factors, and the MESV model is integrated into MCCAM. This paper also quantitatively assesses environmental degradation phenomena in a comprehensive analytical model, which is characteristic of many models. Secondly, this paper fully considers the phenomenon of environmental degradation in land development and utilization projects, and quantitatively estimates the cost of environmental degradation. Finally, this paper introduces the cobweb model, which is convenient for modifying the parameters of MCCAM, and also considers the delay factor and timeliness. From the model results, MCCAM evaluates the economic benefits of land development projects and the cost of environmental impacts in many aspects, and provides a quantifiable evaluation system for humans to develop land rationally.

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