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Research on the Method of Assessing the Ecological Profit and Loss of Highway Construction in Karst Landform

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Abstract: Karst landform is a special geological landform with unique geomorphological and ecological features, which is highly ecologically sensitive and vulnerable to external disturbances. Nowadays, the process of highway construction in China is developing rapidly, and the social and economic development will cause certain environmental impacts at the same time. Highway construction in karst landform areas will inevitably affect the local ecological environment during the construction and operation of the project. Therefore, it is of great significance to carry out the research on the ecological and environmental profit and loss assessment method of karst terrain highway construction, using the cost-effectiveness method to assess the environment, selecting the ecological profit and loss and environmental profit and loss evaluation indexes, and assigning each profit and loss index a different weight and monetary value, and ultimately judging how much impact is generated in the form of monetization. This method of analysis is of guiding significance for the construction of highways in designated karst landforms.

Keywords: Karst Landform, Highway Construction; Ecological Environment Profit and Loss Assessment; Cost-effectiveness Approach

1. Introduction

In recent years, with the rapid development of China's economy, highway construction has developed rapidly, the highway network system has become more developed, and the process of urbanization has gradually accelerated. However, the highway construction also breaks the balance of the original ecological environment in the highway construction area, which will have an impact on the ecological environment of the road area during the construction and operation of the highway project[1]. For example, it causes soil and water loss, vegetation reduction, rock desertification and other ecological damage in the local environment[2,3]. Moreover, because of the unique ecological environment structure of karst landform, its ecological fragility is high and it is easy to be affected by external interference[4]. Therefore, the damage to ecological environment caused by road construction in karst areas is more serious than that in other regions. Karst landform is an indispensable part of the earth's biosphere. Therefore, it is necessary to carry out highway construction on the basis of protecting the ecological environment, make different planning and design and formulate environmental protection schemes according to the actual ecological environment situation of the highway construction area, and build "ecological highway" to achieve a win-win situation of infrastructure construction and ecological environmental protection[5].

In order to realize the environmental protection in the process of highway construction, it is necessary to evaluate the ecological environment profit and loss of the construction area, analyze the ecological service function profit and loss caused by highway construction, use the economic evaluation method and establish a mathematical model, and standardize the data of ecological environment profit and loss through currency[6]. In this paper, the basic principles of cost benefit and ecological environment value evaluation method are

comprehensively applied to convert ecological environment profit and loss into social and economic value, which can be expressed in monetary terms. This analysis method is widely used in the field of environmental economics, with high scientific and accurate, through the analysis of ecological environmental profit and loss, to achieve the purpose of providing theoretical basis and guiding significance for the construction of karst landform road and ecological environmental protection.

2. Road Ecological Profit and Loss Analysis

Method

Combined with a large number of current literature, it is found that the ecological profit and loss assessment methods for highway construction are most commonly used in environmental economics, and three types of ecological economic damage and benefits are most used in environmental economics: direct market valuation approach, revealed preference approach, stated preference method[7]. The meanings and comparison of the three methods are shown in Table 1 and Table 2.

Table 1. Meaning of Economic Assessment Method for Ecological Environmental Profit and Loss

Method type	Implication
Direct market valuation approach	Environmental quality is regarded as a production factor, and its impact on environmental quality change is evaluated based on the change in productivity[7].
Revealed preference approach	Study people's participation in the market, people's spending and benefits in environmentally relevant markets, predict people's environmental preferences, and assess the economic value of environmental change. The alternative market prices are used to evaluate environmental products without market prices[8].
Stated preference method	A survey based method of assessing the service value of non-market goods, in which the value of the relevant goods is guided by a questionnaire, the result of which depends on the characteristics of the goods or services described in the establishment of the market and the survey scheme[9].

Table 2. Comparison of Ecological Environment Profit and Loss Value Assessment Methods

Name	Application situation	advantage	shortcoming
Direct market valuation approach	Causality is clear, and environmental gains and losses are expressed in the form of currency.	Easy to understand, intuitive, easy to calculate and adjust.	It is difficult to analyse the main causes of profit and loss and to assess the causal relationship.
Revealed preference approach	Traffic noise; Nature reserves, forest parks; Railway, road planning, etc.	The value of ecological environment can be calculated indirectly by substitutable products.	Alternative products can not fully reflect the value of ecological environment, but can only reflect the comprehensive factors or partial characteristics[10].
Stated preference method	Leisure and entertainment, protection of resources without market prices, biodiversity, impact on life and health, etc.	Can fully evaluate the value of an item's use.	Have a deviation; Inconsistent willingness to pay and receive compensation; It is difficult to summarize the sampling results[11].

3. The Principle of Ecological Assessment Index System Selection

Ecological assessment index is the evaluable attribute of ecological environment entity. Ecological assessment index system refers to a whole composed of many different ecological indicators, facing different research objects, according to the purpose of research, to obtain specific research objects in all aspects. In the ecological assessment index system, the selection of indicators should follow certain principles, be comprehensive and representative, and the investigation method should be simple. Each indicator should also be measurable and highly independent, avoid the overlap of relevant information among indicators, and try not to have causality between indicators[12]. The implication are shown in Table 3.

Table 3. Selection Principle of Ecological Assessment Index System

Selection principle	Implication
Scientific principle	It must be built on the basis of scientific research, must conform to the theoretical basis, and can reflect the characteristics of the ecological environment in the road from the time and space scale. The collection, calculation and statistical methods of indicators should be reasonable and implemented in accordance with the requirements of national and industry standards, so as to improve the reliability, authenticity and objectivity of the evaluation system[13].
Representativeness principle	There are many factors involved in the ecological environment profit and loss assessment, so it is not necessary and no possible to select all the factors in the actual evaluation. It is only necessary to consider whether the selected indicators can represent the entire evaluation process and whether they can reflect the status quo and changes of the local ecological environment[14].
Systematic principle	Different regions have different ecological environments, forming a complex ecosystem, which is interrelated. Therefore, before establishing a complete evaluation system, it is necessary to clarify the relationship between various evaluation indicators and determine the corresponding level according to the correlation theory. Indicators should be closely connected. When selecting indicators, it is necessary to consider not only the representative significance of a single indicator, but also the synergistic effect among them[15].
Quantitative principle	The investigation and calculation of indicators should be quantified, so as to make them more consistent and accurate with the evaluation standards, and finally obtain reliable and objective evaluation results, reduce human interference and operational errors in the evaluation process, and ensure the objectivity and scientificity of indicator data[16].
Stability principle	The index should be stable, not highly sensitive to other variables, and it will only change slightly or not when the associated variable changes. Otherwise, the value of some indicators will be difficult to calculate and determine, which will affect the accuracy of the research[17].

4. Ecological Environment Economic Profit and Loss Analysis Evaluation Index

Cost-benefit analysis is the most commonly used method of eco-environmental economic profit and loss analysis, which can be used to identify and measure the overall benefit of a highway construction project. Project benefit is the value added of the output of goods and services of the project, including environmental goods and services, that is, the sales economic benefit and environmental improvement benefit of the production[18]. In the ecological environment economic profit and loss analysis, it is necessary to find out the main environmental impact problems of the project and carry out economic profit and loss analysis.

4.1 Economic Net Present Value (ENPV)

Calculate the actual revenue value of the project taking into account the time value of funds. It is the ratio of the economic net present value to the total investment present value, that is, the economic net present value of the unit investment present value. The calculation formula is as follows:

$$ENPV=\sum_{i=1}^{n}\frac{B_i-C_i}{(1+r)^i} \quad (1)$$

Bi, Ci—Total environmental protection benefits and total investment costs incurred in i-th year.

r—Social discount rate (%).

When ENPV>0, it indicates that the environmental investment in the project has paid off.

4.2 Economic Net Present Value Rate (ENPVR)

When there are multiple environmental projects to choose from, choose the project with a larger ENPV value:

$$ENPVR=\frac{ENPV}{Ip} \quad (2)$$

ENPV—net present value of economic benefit.

Ip—net present value of investment.

4.3 Benefit-cost Ratio

$$E=\frac{B}{C} \quad (3)$$

PVB - benefit present value.
PVC - cost present value.
The higher the calculated value E, the better the return on investment. The basic rule is E>1[19].

5. Ecological Environment Profit and Loss Assessment Indicators

This paper obtains the research and evaluation methods of ecological environmental profit and loss through literature and field investigation. The obtained ecological environmental profit and loss evaluation index is screened to get its weight, and the ecological environmental profit and loss of highway construction is evaluated to determine the application of a better evaluation system. At present, the ecological environment profit and loss evaluation methods of highway construction generally include grey comprehensive evaluation method, analytic hierarchy proces, Data Envelopment Analysis, Artificial neural network evaluation method, fuzzy comprehensive evaluation[20]. The advantages and disadvantages of each method are compared in the following Table 4:

Table 4. Comparison of Advantages and Disadvantages of Evaluation Methods

Method class	Method name	Advantage	Shortcoming
Theory of Grey system[21]	Grey association analysis method	The calculation is simple and the sample size is small.	Lack of objectivity.
Evaluation methods of operations research[21]	Analytic hierarchy proces	Qualitative and quantitative combination, accurate and reliable.	Difficult to provide new solutions.
	Data Envelopment Analysis	More objective weight design.	Only relative efficiency can be assessed.
Intelligent assessment	Artificial neural network evaluation method	Can handle nonlinear relations.	Requires training to run.
Fuzzy comprehensive evaluation	Fuzzy comprehensive evaluation	Qualitative and quantitative combination, provide a large amount of information, has a strong ability to expand.	The calculation is complicated and the determination of index weight vector is subjective.

According to existing studies, the impact of highway construction on the natural environment can include natural resources and environmental protection, as well as two time-scales of short-term impact and long-term impact. Therefore, the ecological environmental profit and loss of highway construction is divided into ecological profit and environmental profit and loss, a specific evaluation index system is formed[22], and its weight index is determined.

5.1 Ecological Impact Profit and Loss Assessment Indicators

The short-term impact of highway construction on ecology mainly refers to the destruction of vegetation, rocky desertification, soil and water loss, etc., caused by road construction, while the long-term impact leads to the damage of animal and plant habitats, affects the normal life activities of organisms, and changes the normal law of biological community succession, resulting in serious impacts on relevant ecosystems, Ecological profit and loss evaluation indicators are shown in the following Table 5.

5.2 Environmental Impact Profit and Loss Assessment Indicators

The short-term impact of highway engineering on the environment mainly includes air pollution, water pollution, noise pollution and garbage pollution caused by road construction. Long-term impacts on the environment include air pollution due to vehicle exhaust emissions, soil pollution, noise pollution from vehicle operation, water pollution caused by discharged waste, and some solid waste pollution. Environmental profit and loss evaluation indicators are shown in the following Table 6.

Table 5. Ecological Profit and Loss Evaluation Index System

Time	Primary index	Indicator meaning
Short-term	Ecological destruction	The occupation of land leads to the change of soil utilization type in the construction area, resulting in economic losses and ecological environment destruction in the

		region along the line.
	Soil and water loss	It causes disturbance to the surface and changes the water system structure in a certain range, which is easy to cause soil and water loss.
Long-term	landform pattern	The highway construction leads to the change of land use along the road, and then causes the change of landform pattern in the road area.
	Service function	Land cover leads to changes in land use types, resulting in changes in land cover of different ecosystem types.
	Road death	Road traffic kills a lot of wildlife. With the rapid progress of the transportation industry, the incidence of traffic accidents is gradually increasing.
	Blocking effect	Highway construction divides the places where animals live into several small areas, reducing the range of animal activities, affecting the growth and reproduction of animals, reducing the quality of the population and reducing the communication between the populations, resulting in a more far-reaching impact on biodiversity.
	Species invasion	Animals or vehicles can carry alien species into local ecosystems, and new roads can provide a mobile invasive route for alien species [23].
	Ecological process	The decrease of vegetation coverage will affect the original development trend of the biological community. In addition, the construction of highways will cause the originally connected land and water to be divided into isolated plates, which will have a negative impact on the geological structure and water system structure [24].

Table 6. Environmental Profit and Loss Evaluation Index System

Time	Primary index	Indicator meaning
Short-term	Air pollution	Air quality can be affected by factors such as construction dust, vehicle exhaust, and smoke generated when asphalt is laid.
	Water pollution	Water environment is affected by pollution caused by building materials stacking, earthwork excavation and filling, drilling and grouting, concrete pouring, domestic sewage in living areas, and oil pollution from construction machinery and vehicles [25].
	Noise pollution	Including the noise emitted by various types of construction machinery and vehicle transportation noise [23].
	Garbage pollution	Building materials stacking, construction waste, engineering waste, domestic waste, will cause land hardening, soil pollution.
Long-term	Air pollution	There are a variety of pollutants in vehicle exhaust, which can not only directly harm the normal life activities of humans and animals and plants, but also change the type of climate when the production reaches a certain level, thus affecting the natural ecology of the whole world. Air pollution in the road area focuses on the impact of vehicle exhaust on the environment [26].
	Water pollution	Pollutants released by construction machinery and vehicles (such as heavy metals, microplastics, etc.) and pollutants generated by various construction measures and building materials will enter the road water body or penetrate into the groundwater along with the road rainwater runoff. These pollutants continue to accumulate, and when they exceed a certain range, they will threaten the safety of water quality.
	Noise pollution	It mainly refers to the combustion noise, intake and exhaust noise, fan rotation noise, mechanical noise, tire noise, body noise, etc., and also includes the noise generated by construction machinery work.
	Soil pollution	The main road of the highway and its surrounding areas will accumulate more heavy metal particles, forming an area with a width of nearly 50-100 meters on both sides of the road, and the concentration of heavy metals in this area shows a gradual decline from inside to outside [24].
	Waste pollution	Waste pollution includes abandoned machinery, construction waste, household garbage, scattered earth, cement and so on. Some of these wastes have strong resistance to heat, wear and degradation. It exists in the open air for a long time, and it will pollute the local soil and water source after being soaked by rain.

5.3 Determine the Weight of Ecological Environment Profit and Loss Impact Indicators

5.3.1 Weight determination based on analytic hierarchy process

The weights of this paper are determined according to the scores of several experts, and the importance judgments of experts on indicator weights are converted into weight representations. The value of indicator weights is shown in Table 7 (This weight indicator is

referenced from the results achieved in the early work phase of the project——Ecological environmental profit and loss analysis of western highway engineering and the evaluation of road ecological engineering effect).

Table 7. Ecological Environment Profit and Loss Evaluation Index System Factor Weight Table

Type	Index	Weight	Type	Index	Weight
Ecological profit and loss evaluation index	Ecological destruction	0.257	Environmental profit and loss assessment indicators	Air pollution (short term)	0.038
	Soil and water loss	0.189		Water pollution (short term)	0.059
	landform pattern	0.127		Noise pollution (short term)	0.041
	Service function	0.090		Air pollution (long term)	0.110
	Road death	0.090		Water pollution (long term)	0.139
	Blocking effect	0.095		Noise pollution (long term)	0.162
	Species invasion	0.095		Soil pollution (long term)	0.175
	Ecological process	0.058		Waste pollution (long term)	0.214

5.3.2 Evaluation model construction

The function of weight is to reflect the importance and relevance of different evaluation indicators, and also to reflect the status and function of evaluation indicators in the entire evaluation system and the degree of influence on the overall index [26]. According to the above indicators and their weights, it can be seen that among the indicators of ecological profit and loss assessment, ecological destruction, soil and water loss and landform pattern have a bigger weight, while among the indicators of environmental profit and loss assessment, waste pollution, soil pollution, noise pollution, water pollution and air pollution have a bigger weight. The index weights determined by analytic hierarchy process have a smaller value, and the weights with a smaller value have a smaller impact on the ecological environment. In the evaluation index system, the score of the impact degree of indicators on the ecological environment is determined according to the actual investigation results, empirical analysis and expert evaluation [27]. The score is based on the 10-point system, and the grade scores of "9, 7, 5, 3 and 1" respectively represent high impact, large impact, average impact and small impact. The impact is small to carry out quantitative assignment of qualitative indicators. Combined with the existing research conclusions, and then according to the characteristics of karst landform highway, make a comprehensive evaluation. The evaluation steps are as follows:

(1) Establish the hierarchy of evaluation indicators

The indicators are divided into two categories: major indicators and single indicators;

Large scale index: F_i is a Large scale index;

Single index:F_{ij} is the score of the j-th single index within the i-th Large scale index.

(2) The method of determining the scores of indicators at all levels

I. The average value of individual indicators can be obtained according to the type of indicators and the specific evaluation questionnaire;

II. The score of Large scale index is a summary of Single indexs.

$$F_i = \sum W_{ij} F_{ij} \quad (4)$$

In the formula:W_{ij} is the weight of the j-th single index within the i-th Large scale index; F_{ij} is the score of the j-th Large scale index within the i-th Large scale index.

(3) Calculation of comprehensive valuation

The comprehensive evaluation value is a further synthesis of the evaluation value of the major indexes, and its size reflects the degree of impact on the ecological environment of karst landform. The calculation formula is as follows:

$$A = \sum_{i=1}^{n} W_i F_i \quad (5)$$

In the formula:A— the impact of karst road area engineering ecological environment quality; n—number of evaluation indicators; WiFi—The value of an evaluation score under an evaluation index; Wi—Shows the weight of the i-th Large scale index; Fi—the evaluation score of the i-th Large scale index.

In order to combine the characteristics of karst highway region, this paper mainly analyzes the ecological damage caused by highway construction, uses the economic evaluation method of ecological environment impact to evaluate the ecological environment profit and loss, incorporate its results into the national economic evaluation, in order to realize the sustainable development of highway construction.

6. Conclusion

At present, the research on ecological environment profit and loss assessment methods for the construction of karst landform highway has achieved certain results. Appropriate economic assessment methods for ecological environment profit and loss are selected to determine the corresponding ecological environment economic profit and loss assessment indicators and ecological environment profit and loss assessment indicators. After standardizing the index data and assigning weights, the evaluation model is constructed to help judge the ecological environment quality of karst road construction area. Then, through the method of environmental economics, the profit and loss caused by highway construction on the ecological environment of the road area is presented in the form of currency, and the comprehensive impact of the highway project on the ecology, society and economy is assessed. In terms of evaluation methods, this paper has formed a relatively complete evaluation system, including the comparison of common ecological profit and loss evaluation methods, the selection principle of ecological evaluation index system, the evaluation index of ecological environment economic profit and loss analysis, and the evaluation index of ecological environment profit and loss. In practical application, these assessment methods have been widely applied and verified, providing important technical support for the ecological environment protection of highway construction in karst areas, and playing a guiding and complementary role in the assessment methods of ecological environment profit and loss of road areas in karst areas.

However, there are still some problems and challenges. First of all, the geomorphology and ecological environment of karst area are very complicated, which brings great difficulties to the monitoring of assessment indicators in ecological environmental profit and loss assessment. Secondly, the current ecological environment profit and loss assessment method is not perfect, different methods have different advantages and disadvantages, still need to be further perfected and improved. In terms of ecological environmental damage assessment, it is necessary to consider various ecological environmental factors more comprehensively and select more representative assessment indicators to assess the ecological environmental loss and profit of highway construction more accurately.

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