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Optimization Design of Expressway in Natural Environment Protection Area Based on Neural Network

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Abstract: Expressway has become an important mode of transportation, but the natural environment along the highway has also been greatly damaged. There are many unreasonable aspects in the highway design in many nature reserves and scenic spots. In this paper, the expressway from section A to section B of a province was taken as the research object. Through collecting the data of geological environment, natural environment and human environment along the expressway, the analytic hierarchy process (AHP) was used to analyze the influencing factors of expressway design in the natural environment protection zone. In this paper, the optimization design model of expressway in natural environment protection area was established by combining neural network (NN for short here). The results show that the route length, subgrade width, bridge and culvert length and tunnel length optimized by the NN model were 92km, 18m, 14km and 11km respectively under the same other conditions. The route length, subgrade width, bridge and culvert length and tunnel length optimized by the traditional model were 98km, 19m, 16km and 14km respectively. The data of the former was obviously superior to that of the latter, which showed that the relationship between NN and highway optimization design in natural environment protection areas was positive.

1. Introduction

People's awareness of environmental protection is becoming stronger and stronger. However, due to many factors involved in the process of highway construction, many highway projects cannot effectively protect their surrounding natural environment, especially in the nature reserves near the highway project. At present, the research on environmental impact assessment of highway projects in China mainly focuses on the following aspects: the impact of highway construction on soil,

vegetation and other natural environment, as well as the impact on biodiversity. However, the research on the impact of highway construction on the natural environment mainly focuses on vegetation destruction, soil erosion, ecological environment deterioration and other aspects. Although these research results proposed protection measures from different aspects, they did not consider the comprehensive benefits of ecological protection measures as a whole.

In practical work, many highway construction projects have not considered the surrounding environmental factors, resulting in a certain degree of damage to the natural environment after the completion of the highway. For highway construction projects, if environmental protection factors are not considered in the design process, it would pose a great threat to the surrounding environment. Artificial neural network (ANN) is a new nonlinear computing model that simulates the structure and function of human neural system. It has good ability to process complex information and memory. The ANN method is a new model developed based on the traditional linear model. It can map complex, nonlinear and uncertain data into regular data structures through a large number of nodes and connecting elements to form a network. At the same time, because of the strong self-learning ability of NN algorithm, it can solve complex problems that are difficult to solve in practical problems.

Based on this, this paper would study the optimization design of expressway in natural environment protection areas based on NN model, and use AHP algorithm to analyze. Through the optimization effect of the two models on the expressway from section A to section B, this paper concludes that the NN model is conducive to the optimization design of the expressway in the natural environment protection area.

2. Related Work

Due to the rapid development of expressway, people have also made a lot of research results on it. Speed limit is an effective means to ensure passenger safety. In order to improve the scientificity of the speed limit standard of mountain expressway, Xie Z. proposed a new method for formulating the speed limit and a specific speed limit implementation scheme for multi-curve sections. The results show that when the radius of curvature of the road is large, the critical speed of vehicle rollover and sideslip is high. In particular, when the cross slope value of the road section is quite large in a limited range, the critical speed of vehicle side rollover is very high [1]. In order to study the dynamic traffic assignment problem of large expressway network, especially in the case of traffic events (such as bad weather, large traffic accidents, etc.), Du L. proposed an approximate solution algorithm based on network flow theory, which has high computational efficiency and strong applicability [2]. However, these are mostly theoretical studies on expressway, and lack of a scientific method to conduct more in-depth analysis of its optimization.

In view of the above problems, using NN to optimize the design of expressway in natural environment protection areas has become the topic of more and more scholars, and a lot of research has been carried out in related fields. Wang Junhua has worked out the prediction of highway crash risk, taking into account the impact of key safety events and traffic conditions. The results show that the traffic toughness theory can explain the relationship between traffic conditions, safety critical events and collision risks, which are key elements in the field of road safety. The introduction of security elasticity may stimulate further exploration of this topic in research and practice [3]. Because reliable mechanical parameters of surrounding rock are very important for accurately predicting tunnel deformation. Therefore, Zhou G. proposed a NN back-analysis system based on GA-BP, which realized the automatic search of BP network parameters, greatly improved the efficiency of back-analysis, and was conducive to the safety of highway tunnels [4]. These studies show the applicability of NN in expressway, and lay a solid foundation for combining it with the

optimal design of expressway in natural environment protection areas.

3. Construction of Neural Network Model

3.1. Neural Network

The NN system is composed of a group of interconnected neurons. Each neuron is connected by synapses and transmits information to each other in a nonlinear way. Neural network is an information processing system, which processes information by simulating human perception. Its main research directions are as follows: NN can realize any complex nonlinear mapping, and can be applied to image processing, pattern recognition, computer vision, prediction and other fields. In highway engineering construction, it is regarded as a multi-input and multi-output complex system, which has the characteristics of complex structure and nonlinear mapping. Therefore, NN is used to optimize highway construction schemes.

3.2. Scheme Design and Optimization

During the construction of the expressway in the natural environment protection area, the construction unit usually adopts the method of changing the design to reduce the impact on the surrounding environment [5-6]. This method mainly includes the following three ways: first, in the route design stage, reduce the damage to the environment by adding special subgrade, optimizing the plane alignment of the route, and adjusting the drainage design; Second, reduce the impact on the environment by changing materials and other ways in the construction stage; Third, in the later stage of operation and maintenance, the impact on the environment can be reduced by adjusting the charging standard, maintenance and repair, traffic control, etc. However, no matter which method is adopted, the construction unit shall try to avoid damage to the environment. When adopting NN model for scheme design and optimization, the following points should be considered:

(1) The expressway model established in the model should be consistent with the actual project.

(2) The model shall meet the actual needs of the project and have good adaptability.

(3) In the design process, people should try to consider the possible situation in the future and provide reasonable and effective solutions.

(4) In the actual design process, the whole design work cannot be ignored because of individual projects. The final scheme can only be determined after the design of the whole project is completed.

(5) The model should have strong generalization ability and fault tolerance ability. Even when the number of samples is small, the whole sample can be accurately predicted.

3.3. Analytical Hierarchy Process

AHP is a decision-making method that classifies all the factors involved in the decision-making problem according to the objectives, criteria, plans and other levels, and carries out qualitative and quantitative decision-making on these levels. Its application fields are displayed in Figure 1:

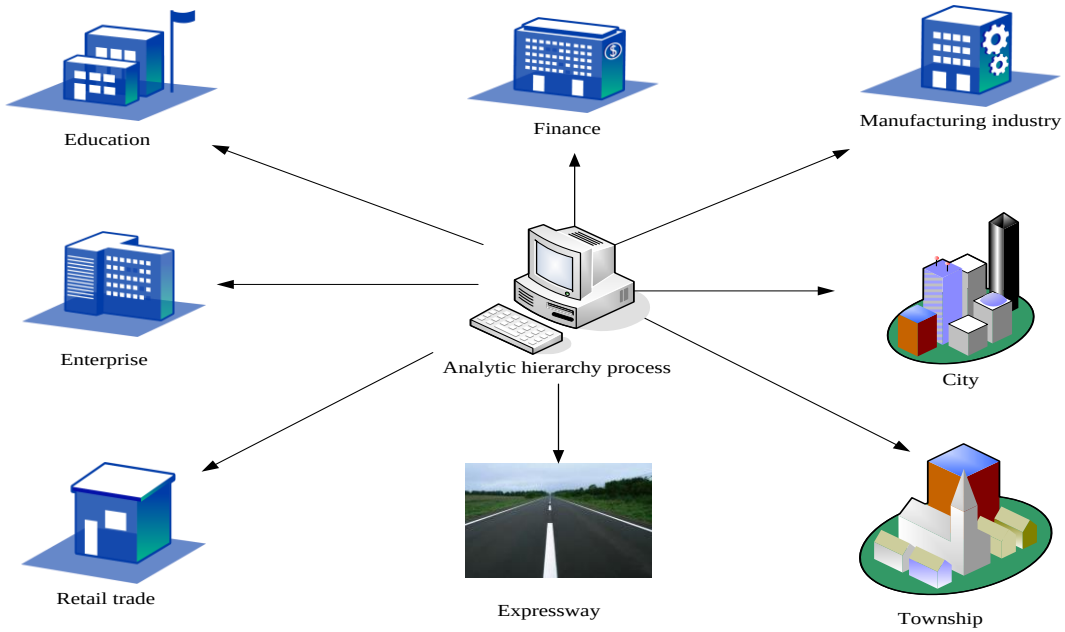


Figure 1. Application of AHP

(1) Establish hierarchical hierarchy

First of all, divide a relatively complex problem into various indexes, and divide it into several categories according to its attributes, thus forming a multi-level evaluation system. Taking the index at the same level as the standard has guiding significance for the index at the next level, but it is also controlled by the index at the next level. The top layer is usually the only one, called the target layer. This intermediate level is usually the criterion level or its sub-index level. The evaluation of expressway nature reserves is a comprehensive evaluation of multiple factors. On the basis of collecting the integrity and relevance of the preliminary survey data, an evaluation system of expressway nature reserves with three levels and three evaluation factors is constructed [7-8].

(2) Establish judgment matrix

It is a key step of AHP. The judgment matrix represents the status of evaluating the relative importance of each relevant element in the upper level for a certain element. There are M indicators, $\{X_1, X_2, \ldots, X_m\}, x_{ok}$ which represent the judgment value of relative importance. Then expressed as a judgment matrix in the form of matrix, people can get:

$$X{:}\,X = \begin{pmatrix} \frac{e_1}{e_1} & \cdots & \frac{e_1}{e_m} \\ \vdots & \ddots & \vdots \\ \frac{e_m}{e_1} & \cdots & \frac{e_m}{e_m} \end{pmatrix} \tag{1}$$

Obviously, for any judgment matrix:

$$x_{ok} = \begin{cases} 1 \; o = k \\ \frac{1}{x_{ok}} \; o \neq k \end{cases} (o, k = 1,2,\ldots,m) \tag{2}$$

Therefore, when building the judgment matrix, people only need to write the upper triangular part, which is usually built with the participation of experts.

(3) Consistency test of judgment matrix

To check the consistency of the judgment matrix, its consistency index can be calculated:

$$CI = \frac{\mu_{max} - m}{m-1} \tag{3}$$

When CI is 0, the judgment matrix has complete consistency; on the contrary, the larger the CI, the worse its consistency. Through the above methods, people can effectively judge the optimal design of expressway in natural environment protection areas under the two models [9-10].

4. Experimental Analysis of Expressway Optimization Design in Natural Environment Protection Area

4.1. Expressway Development

In the 1980s, the construction of China's expressways had just begun, and since then it has been developing rapidly [11-12]. In 2004, the State Council reviewed and approved the National Expressway Network Plan, which includes 7 "capital radiation", 9 "north-south vertical lines" and 18 "east-west horizontal lines" to form the "7918" network [12-13].

Compared with other countries, China's road construction started relatively late, and the first road officially opened to traffic was only in 1988 [14-15]. However, in recent years, China has attached great importance to and supported highways, and its investment has also been increasing. The overall development speed is very fast. According to statistics, the national highway construction investment would reach 1.52 trillion yuan in 2021. The growth of China's highway construction investment from 2015 to 2022 is displayed in Figure 2:

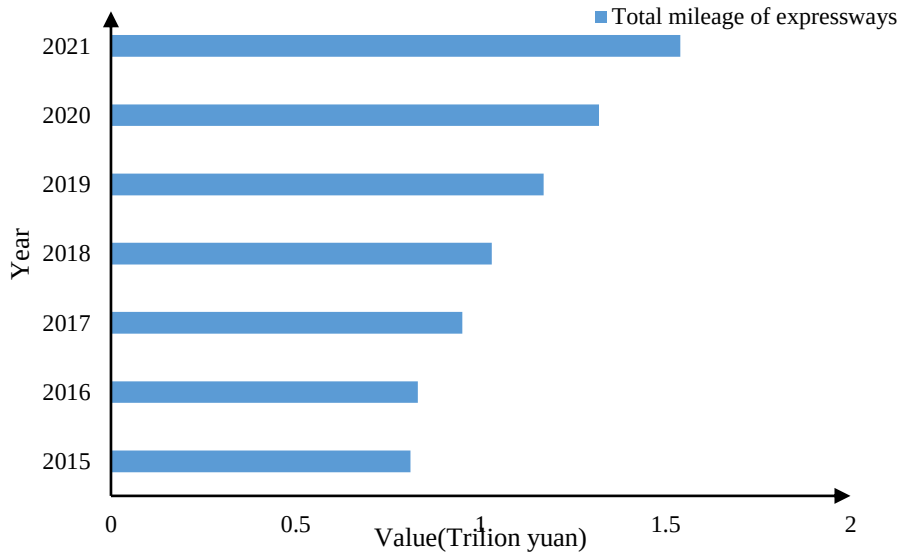


Figure 2. Investment growth in China's highway construction from 2015 to 2021

It can be seen from Figure 2 that the investment in expressway construction in China is increasing year by year, and the scope is increasing, which shows that the scale of expressway construction is also increasing.

With the increasing investment, the speed of highway construction in China is also increasing, and the total mileage is also increasing. According to the Statistical Bulletin on the Development of Transportation Industry in 2021 issued by the Ministry of Transport, the total mileage of expressways across the country has reached 169100 kilometers by the end of 2021, ranking first in the world. The mileage growth of China's expressways from 2015 to 2022 is displayed in Figure 3:

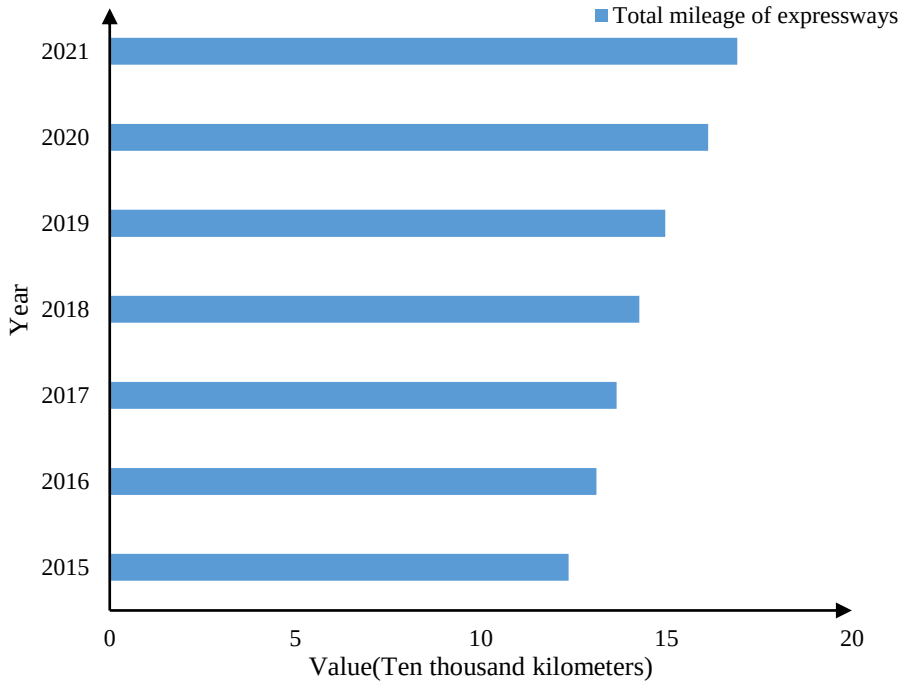


Figure 3. Total mileage of China's expressways from 2015 to 2021

It can be seen from Figure 3 that the total mileage of expressways in China is increasing year by year, and the range is also increasing, which is easy to have a great impact on the ecological environment of natural environment reserves. How to ensure the continuous increase of the total mileage of the expressway without affecting the ecological environment of the natural environment protection area is an urgent problem to be solved. Therefore, this paper proposes to study the optimization design of expressway in natural environment protection areas based on NN model.

4.2. Comparative Experiment of Two Models

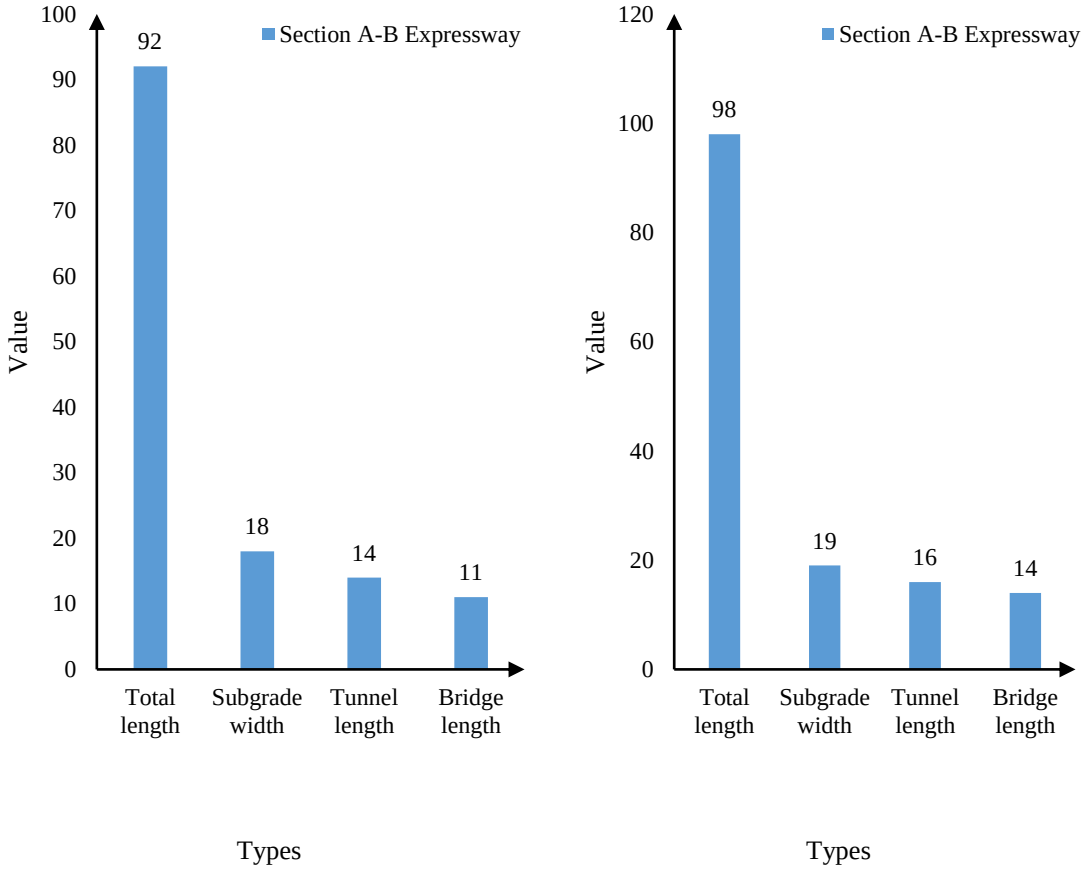
In order to verify the relationship between the prediction model of NN and the optimal design of expressway in natural environment protection areas, this paper first selects the expressway from A to B in a city as the experimental object. This paper then collects the data of geological environment, natural environment and human environment of this section, and makes statistics. Then it uses the AHP to analyze these data, and combines the NN to establish the highway optimization design model of the natural environment protection area. Finally, this paper sets up a simple comparative experiment to get the relationship between the two. The basic information of the study object is displayed in Table 1:

Table 1. Basic conditions of section a-b expressway

Construction time	April 15, 2020
Completion time	March 24, 2022
Total length	100km
Subgrade width	20m
Tunnel length	18km
Bridge length	15km

In this paper, the NN model and the traditional model would be used to optimize the design of the A-B section of the expressway. By comparing the size of the route length, subgrade width,

bridge and culvert and tunnel length under the optimized design of the two models, the results are displayed in Figure 4:



(a) Neural network model *(b) Traditional model*

Figure 4. Optimization design of expressway section A to B by two models

It can be seen from Figure 4 (a) that the route length, subgrade width, bridge and culvert length and tunnel length optimized by the NN model are 92km, 18m, 14km and 11km respectively. It can be seen from Figure 4 (b) that the route length, subgrade width, bridge and culvert length and tunnel length optimized by the traditional model are 98km, 19m, 16km and 14km respectively. It can be seen from Figure 4 that the optimization effect of the NN model is significantly better than that of the traditional model, which shows that the NN is helpful for the optimization design of the expressway in the natural environment protection area.

5. Conclusion

This paper compares and analyzes the effects of traditional model and ANN model in environmental protection, and the results show that the NN model has higher accuracy and feasibility compared with traditional methods. At the same time, this paper applies the ANN technology to the highway optimization design in the natural environment protection area, which can effectively protect the environment along the highway on the premise of meeting the requirements of the highway design specifications, and achieve the harmony and unity of the highway design and the natural environment. However, since the construction of the network model in this paper is based on the theoretical basis of ANN, it needs to be improved in its practical

application. In addition, in order to achieve the goal of more efficient, accurate and rapid, people should further improve the methods and technical means of NN model construction to further improve the effect of NN model construction.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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