

Regional Logistics Demand Prediction Using BP Neural Network Based on Particle Swarm Optimization

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Abstract: Accurate regional logistics demand prediction is an indispensable part of a scientific and reasonable logistics construction system. This article mainly uses machine learning methods to screen features, select effective features, and then uses intelligent algorithms to optimize the BP neural network. The optimized model is trained and predicted for the future, optimizing research on regional logistics demand prediction, and providing effective suggestions for the development of the logistics industry. This article first uses the random forest algorithm to select features, eliminate redundant features, and then uses particle swarm optimization algorithm to optimize the parameters of the BP neural network to improve model performance. Finally, grey prediction is used to construct a prediction dataset, and the future trend of regional logistics demand is predicted, based on which suggestions are proposed. The results show that the optimized combination model proposed in this article can effectively improve prediction accuracy and make an effective contribution to the development of regional logistics.

Keywords: Logistics forecasting; PSO algorithm; BP neural network; RF.

1. Introduction

With the rapid development of the economy, logistics development opportunities and challenges co-exist, regional logistics demand forecasting for logistics development planning, project decision-making to provide a scientific basis, but logistics demand is non-linear, instability and other characteristics, it is difficult to grasp its development trend, affecting the rapid development of regional logistics economy. To address this issue, this paper attempts to use algorithms and data to build a reasonable mathematical model of regional logistics demand for reasonable forecasting, the construction of China's logistics and transportation system, the planning and layout of logistics enterprises, the improvement of the quality of logistics services are of great significance.[1] .

In demand forecasting, some scholars use traditional statistical methods to forecast demand, such as gray forecasting [2], ARIMA [3] ARIMA, multiple regression [4] In logistics demand, Li Sicong et al. used gray forecasting combined with regression modeling to forecast the demand for cold chain logistics of agricultural products in China[5] In the logistics demand, Li Shapei used the method of gray prediction to grasp the uncertain relationship and change trend in the logistics system, but the traditional statistical methods are difficult to grasp.[6] However, the traditional statistical methods are difficult to grasp the characteristics of unbalanced and sudden demand in the time dimension, and at the same time, with the arrival of the big data era, the analysis of large-capacity and multi-dimensional data also puts forward higher requirements for our forecasting methods.

In order to better process high-dimensional data, neural network processing methods have gradually entered the vision of scholars in China, such as Wang Xinli et al. who utilized BP neural network to predict the logistics demand of agricultural products in China[7] For example, Wang Xinli et al. used BP neural network to forecast the logistics demand of agricultural products in China.[8] He Mengtong and others use BP neural network model to analyze the logistics demand of flowers.[9] He Mengtong et al. used BP neural network model to analyze the demand of flower logistics. However,

BP neural network in the processing of big data is easy to fall into the local optimum, convergence speed is slow, susceptible to feature noise and other shortcomings, to address this issue, scholars use a combination of models to deal with, such as Huang et al. using gray prediction and BP neural network combination, to improve the accuracy of prediction[10] For example, Huang et al. use the combination of gray prediction and BP neural network to improve the accuracy of prediction, and Wang et al. use intelligent algorithms to adjust the parameters of BP neural network to find the optimal parameters and prevent it from overfitting and falling into local optimum.[11] The following is a summary of the results of the study.

In summary, the traditional prediction methods are difficult to predict from the time dimension and space dimension, and although the neural network algorithm is widely used in regional logistics demand, it still has some room for improvement, so this paper seeks the optimization of the BP neural network parameters through the particle swarm algorithm to ensure the performance of the model, and at the same time, considering that in the screening of the features, the dependence on the subjectivity of the people is strong, and the lack of a scientific method of constructing a prediction feature subset is easily interference by data noise, so this paper adopts the machine learning method, introduces the random forest feature screening method to screen the selected impact indicators, and then through the improved BP neural network to predict the logistics demand in typical regions.

2. Analytical Methods

2.1. BP Neural Network

BP neural network is a kind of artificial neural network with back propagation function, which consists of input layer, several hidden layers and output layer, the input signal in the hidden layer of neural nodes through the algorithm given by the initial weights to the output layer, get the predicted value and the real value for comparison, constantly use the gradient descent method for tutored back propagation learning, many times according to the magnitude of the error to constantly

adjust the weights and the threshold, constantly optimize the algorithm process, and finally make the error to reach the minimum.

2.2. PSO Algorithm

PSO (Particle Swarm Optimization) is a heuristic optimization algorithm inspired by the behavior of groups such as flocks of birds or schools of fish. It is a population intelligence algorithm for solving optimization problems such as function optimization, parameter tuning, etc. The working principle can be explained simply as the individuals in PSO are called particles and each particle has a position and velocity vector representing a possible solution in the search space. The particles in PSO adjust their own motion by communicating their experience with other particles. Each particle updates its position and velocity based on its individual experience and group experience, as well as the global optimal solution. The advantages are as follows: (1) Simple and easy to implement and understand. (2) No need for derivative information. (3) Good global search capability. (4) Applicable to continuous optimization problems.

2.3. PSO-BP model construction

2.3.1. Parameter setting

For the inertia weights and learning factors we apply Eq. 1-3 for adjustment

$$W = W_{max} - \frac{W_{max} - W_{min}}{t_{max}} \times t \quad (1)$$

$$C_1 = C_{max} - \frac{C_{max} - C_{min}}{t_{max}} \times t \quad (2)$$

$$C_2 = C_{max} - \frac{C_{max} - C_{min}}{t_{max}} \times t \quad (3)$$

Updating Position and Velocity Using Equation 4-5

$$V_i^{k+1} = wV_i^k + c_1r_1(P_i - X_i^k) + c_2r_2(P_g - X_i^k) \quad (4)$$

$$X_i^{k+1} = (X_i^k - V_i^{k+1}) \quad (5)$$

Where: $i=1,2, \dots, n$; n is the total number of particles, V_i is determined as the velocity of the particle, X_i is determined as the position of the particle, P_i is the individual extreme value, P_g the global extreme value, r_1, r_2 are random numbers uniformly distributed in the interval of (0, 1).

2.3.2. Modeling

After setting the basic parameters of the particle swarm algorithm, the particle swarm algorithm is used to find the optimal weights and thresholds, and the found optimal values are assigned to the BP neural network, and then the BP neural network is utilized for training, resulting in the PSO-BP neural network learning model, and the specific process is shown in Figure 1.

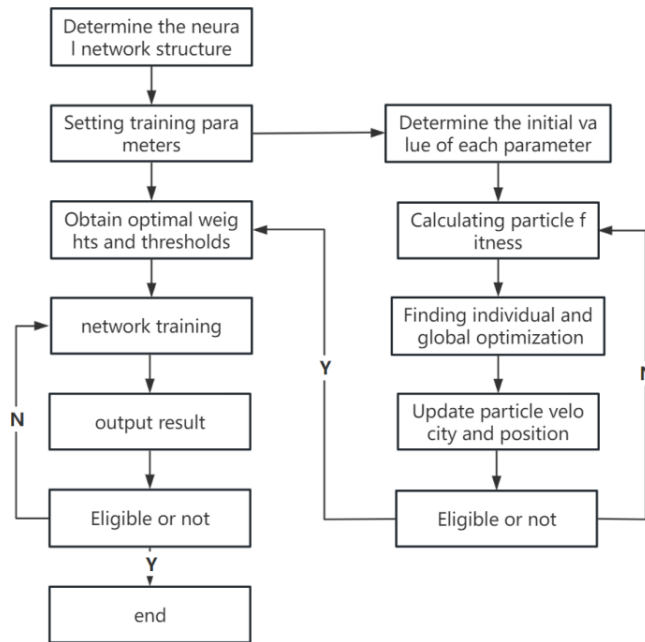


Figure 1. Optimization flowchart

3. Instance Validation

3.1. Research Objectives

Henan Province is located in the central part of the country, and its advantageous geographic location naturally has a good ability to radiate and concentrate. At the same time, the government of Henan Province also attaches great importance to the construction of logistics hubs and the economic pull they can bring. It has issued the "14th Five-Year Plan" and other policies to promote the development of the logistics industry in the province, so that the development of

logistics in Henan Province has a solid foundation, so this paper chooses Henan Province as a typical region for research.

3.2. Analysis of indicators

3.2.1. Selection of influencing factors

Regional logistics demand is affected by a variety of factors, this paper through the combing of multiple literature, as shown in Table 1, based on the principle of accessibility, the selection of regional logistics demand influencing factors. In this paper, the influencing factors are divided into industry endogenous power and objective external promotion, such as

economic factors such as primary, secondary and tertiary industries, demographic factors and consumption level factors are categorized as the objective external promotion, the development of urbanization, the degree of population density to promote consumption upgrading, and to enhance the demand for regional logistics; the amount of investment in fixed assets in transportation, the number of civilian cargo vehicle ownership, etc. as the industry's endogenous power, the advancement of technology and the improvement of the foundation to promote the Industry upgrading, improve service quality, promote the development of regional logistics demand.

In practical application, China has not formed an intuitive evaluation index for regional logistics demand, through the summarization of former scholars and the exploration of practical experience[10,12] Through the summarization of former scholars and the exploration of practical experience, the freight volume (Y1) is chosen as the indicator reflecting

the regional logistics demand, i.e., the output indicator. In order to better utilize the advantages of neural network on big data analysis, and also to improve the prediction performance, considering that the regional logistics demand is affected by many factors, based on the principle of qualitative and quantitative, and taking into account of the previous research and practical experience, we initially choose the Gross Domestic Product (X1), the value of the primary industry (X2), the value of the secondary industry (X3), the value of the tertiary industry (X4), and the total retail sales of social consumer goods (X5), Consumer Price Index (X6), highway mileage (X7), cargo turnover (X8), per capita disposable income (X9), year-end resident population (X10), investment in fixed assets for transportation (X11), value added of transportation, storage and postal industry (X12), ownership of civilian goods vehicles (X13), and ownership of private goods vehicles (X14). indicators are used as forecast indicators, i.e. input indicators.

Table 1. Analysis of Factors Influencing Regional Logistics Demand

explanatory variable	literatures
GDP, total logistics costs, total fixed asset investment, total imports, total exports	Hu Xiaojian et al.[12]
Value of primary, secondary and tertiary industries, total retail sales of consumer goods, per capita disposable income of residents	Li Jie and others[13]
Value of primary, secondary and tertiary industries, total investment in fixed assets, total retail sales of social consumer goods	Jiang Jinde et al.[14]

3.3. Feature Screening

Feature screening can eliminate the influence of redundant data on the model and effectively improve the prediction accuracy of the model. Random forest, as a kind of machine learning algorithm, can effectively discriminate the influence

of different features on the prediction target, and distinguish the effectiveness of features.[15,16] This paper is based on the random forest model for feature prediction. This paper is based on the random forest model to screen the features, eliminate data noise, and analyze the factors affecting regional logistics demand, as shown in Figure 2.

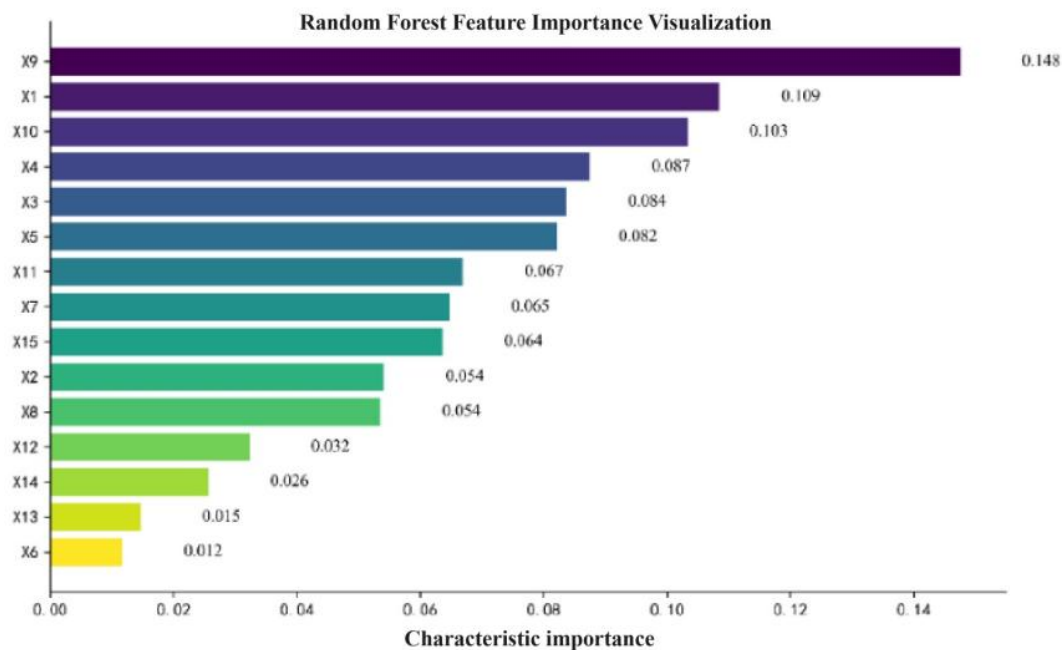


Figure 2. Importance of Random Forest features

Based on the results, seven indicators were selected as predictors: disposable income per capita (X9), gross regional product (X1), resident population at the end of the year (X10), value of the tertiary industry (X4), value of the secondary industry (X3), total retail sales of consumer goods (X5), and

the amount of investment in transportation fixed assets (X11).

3.4. PSO-BP projections

3.4.1. Model training

The set parameters are inputted into MATLAB for setting,

and the imported data are normalized by mapminmax to eliminate the scale between different data. In this paper, the input data and output data of 2005-2022 are selected as training samples. In view of the randomness of the initialization conditions of the network, this paper runs 30 times independently to make the prediction results more accurate.

In this paper, MSE and MAE are chosen as evaluation indexes to evaluate the model performance of BP neural network (N-BP), BP neural network and PSO-BP without feature selection, and the specific data are shown in Table 2. The optimized BP neural network has more obvious advantages for the in-depth learning and analysis of regional logistics demand, while the results show that the random forest feature selection also has excellent performance for data cleaning and eliminating redundant data.

Table 2. Prediction results of various methods

methodologies	MSE	MAE
N-BP	0.70	0.80
BP	0.35	0.53
PSO-BP	0.02	0.15

3.4.2. Model predictions

Gray forecasting is a common forecasting method in short- and medium-term economic development trend forecasting, with simple structure and quantity demand for data, which is widely used in engineering management and other fields. In this paper, we choose to use gray forecasting to analyze the various influencing factors of the regional logistics demand, to generate the dataset suitable for PSO-BP analysis, and to forecast the future using PSO-BP neural network, as shown in Fig. 3.

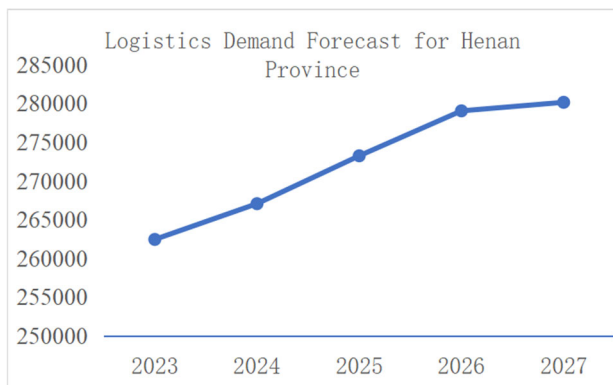


Figure 3. Henan Province Logistics Demand Forecast

3.5. Development proposals

This paper collects the data related to logistics demand forecast in Henan Province from 2005 to 2022, and after screening by Random Forest Feature Importance Analysis, the optimized BP neural network is used to forecast the logistics demand in Henan Province from 2023 to 2027, and it is concluded that the logistics demand in Henan Province in the next five years shows an overall upward trend, and this data can be used as a reference for the strategic plan of the enterprises and the government. At the same time, the forecast results are analyzed and some suggestions are made for the future development strategy of Henan Province:

(1) Promote regional cooperative development strategy. The future development trend of logistics in Henan Province as a whole shows a steady upward development, but the cities

in Henan Province still have the situation of uneven development of logistics, Henan Province should promote the synergistic cooperation of cities within and outside the province, complement each other's strengths, and promote the overall development of the region.

(2) Comprehensively improving the overall service capacity of the modern logistics and transportation network in Henan Province. By taking the optimization of the service chain, the strengthening of service functions, and supply chain synergy as the starting point, it improves the service level of specialized logistics, pushes the modern logistics to expand it to the upstream and downstream of the industrial chain, and promotes the overall upgrading of the entire logistics industry. It not only makes the modern logistics service system in Henan Province better developed, but also lays a solid foundation for upgrading the modern industrial system, promotes the industry to enter the middle and high end of the world value chain, and injects powerful kinetic energy into the development of China's economy.

(3) Increase capital investment and policy support. The government should strengthen the construction of logistics infrastructure, improve roads, bridges and other transportation hubs, and promote the interconnection of logistics regions. Policy support for logistics small and medium-sized enterprises, through tax relief, improve the financing environment and other ways to reduce the pressure on enterprises, and promote the development of logistics enterprises. The government should encourage and actively support enterprises to be market-oriented and strengthen cooperation with third-party logistics. For example, it should appropriately support some third-party logistics enterprises so that they can provide better services for enterprises and promote cooperation between them. [...15] For example, the government should appropriately support some third-party logistics enterprises to provide better services to enterprises and promote cooperation between them.

(4) Promoting the development of modern logistics enterprises. Promote scientific and technological innovation in logistics enterprises, promote the in-depth combination of "Internet Plus" and traditional logistics, improve the level of informatization, accelerate digital transformation, intelligent upgrading and service innovation, and create e-commerce industrial parks integrated with intelligent logistics. Develop green logistics, build a supply chain coordination platform, develop manufacturing logistics services such as lean logistics, and promote the development of industrial integration in various industries.

4. Conclusion

In this paper, we select typical areas, use particle swarm algorithm to optimize the BP neural network, search for the optimal initial weights and thresholds, accelerate the convergence speed, and combine with the random forest feature importance analysis to screen out the effective features, which can improve the prediction ability and stability of the BP neural network more efficiently and effectively, construct a dataset by using grey prediction, and make a prediction of the future based on the optimized BP neural network, and To put forward scientific suggestions to help the government and enterprises to make decisions. This paper analyzes the historical data trend through the gray prediction model, and analyzes the future logistics demand prediction using PSO-BP neural network to help the government and enterprises provide scientific guidance for

decision-making.

The actual results show that the combination model constructed by using Random Forest, Particle Swarm Optimization Algorithm and BP Neural Network proposed in this paper is more accurate than a single model, and the performance of the model has been effectively improved, and its prediction of the future and the suggestions made according to it can effectively provide support for the scientific decision-making of the enterprises and the government.

This paper is affected by the statistical system and caliber, it is difficult to obtain a large amount of detailed data, the trained learning model does not have a large amount of data in the future can look for more comprehensive data, or use other algorithms for optimization.

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