Research on Express Demand Problem Based on Analytic Hierarchy Process, Entropy Weight Method and ARIMA Time Series

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Abstract. Under the background of rapid development of express industry, this article establishes the evaluation model of station city importance and the forecast model of express transport volume by means of analytic hierarchy process, entropy weight method and ARIMA time series model, which has strong practical significance. Firstly, this article preprocess the data to get the daily receipt and shipment of each city. Then, seven indexes are selected as the comprehensive evaluation indexes of each station city, a comprehensive evaluation system based on analytic hierarchy process and entropy weight method is constructed, and the evaluation model of the importance degree of each station city is established. Considering that the number of express delivery varies greatly and irregularly, this article chooses the ARIMA time series analysis model, and determine the coefficient of the ARIMA time series analysis model through the ACF diagram and the PACF diagram, and plug the data into the prediction model to obtain the prediction result of the number of express transportation between stations and cities.

Keywords: Analytic hierarchy process, Entropy weight method, ARIMA time series.

1. Introduction

At present, the evaluation methods mainly adopt subjective evaluation and objective evaluation methods. In the subjective evaluation, data is mainly collected in the form of questionnaire for evaluation [1], while in the objective evaluation, the effect is mainly evaluated by behavioral data. For example, Li Hua [2] used two indicators to reflect the learning effect; Wei Shunping[3] designed the evaluation index system of two dimensions, and used the analytic hierarchy process to determine the weights of indicators at all levels. In addition, some studies have divided online performance into promotion degree and engagement degree, etc[4]. However, the existing evaluation index system is mainly constructed by subjective methods such as analytic hierarchy process, while objective methods based on actual data such as entropy weight method are rarely applied to the construction of evaluation index system.

Jia Pengtao [5] proposed a prediction model based on convolutional neural network and unit neural network by using the spatial characteristics of data, which has certain guiding significance in the field of prediction. Wang Yuhong [6] proposed an optimization algorithm to optimize the prediction model of long and short memory neural networks, improved the optimization algorithm by using Gaussian variation method, and established the prediction model. The error of the model was significantly reduced than that of the traditional model. Fu Hua [7] proposed a sensor prediction model of deep long and short memory neural network. The correlation coefficient method was used to select variables as model parameters, and the prediction performance of the model was good. Zhang Xinjian [8] proposed a prediction model combining long and short-term memory neural network and wavelet threshold denoising. The original data were denoised and then predicted by using long- and short-term memory network. Compared with the traditional model, the prediction accuracy of this model was significantly improved.

In order to rationally layout warehouse sites, save storage costs, and plan transportation routes, it is necessary to accurately predict the number of express transportation needs. From the perspective of the growth or decline trend and correlation of receiving volume, shipment volume and express

delivery volume, we selected seven evaluation indicators, such as total receiving volume, total shipment volume, change rate of receiving volume, change rate of shipment volume, correlation, harvest frequency and delivery frequency, established a comprehensive evaluation model[9] based on analytic hierarchy process and entropy weight method, and ranked the importance of site cities. The ARIMA time series prediction model [10] is used to predict the number of express transportations between the cities of the stations.

2. Establishment and solution of evaluation model

2.1. Construction of evaluation index system

The selection of evaluation indicators should be based on the following principles:

(1) Purpose rationality

(2) comparability and operability

(3) comprehensiveness and tradeoff

Based on the above principles, we selected seven indicators as comprehensive evaluation indicators to rank the importance of each site city:

Total shipments, total shipments, total shipments frequency, total shipments frequency, shipments trend change, shipments trend change, total number of connected cities (i.e., correlation). Among them, frequency refers to the total number of times that the city appears as the shipping city or the receiving city, respectively.

2.2. Evaluation index calculation

Firstly, we use python for processing data (from the 2023 Five Cups Mathematical Contest in Modeling) to obtain the total received volume, total shipments of each city, and the frequency of occurrence as the receiving city and the shipping city respectively.

Then we used the fitting function in Excel to fit the express growth curve of each city according to the existing data, and chose slope K as the quantitative indicator of the growth/decline trend. Finally, in Excel, the delivery city and receiving city of each city are screened, the upstream and downstream connections of each city are obtained, and the total number of connections is obtained by summing them.

The construction of the evaluation index system is shown in the following table 1 (taking cities A, B and C as examples):

Table 1 Evaluation index system table

city	shipment	Quantity received	Delivery frequency	Frequency of receiving goods	Total number of connected cities	Growth rate of shipments	Growth rate of the number of goods received
A	31276	51708	381	818	6	-531.73	-408.62
B	12458	15624	67	66	2	-1931.5	-2932.5
C	18361	13228	543	351	6	-240.95	-174.08

2.3. Selection and construction of evaluation model

By combining analytic hierarchy Process (AHP) and entropy weight method, the importance and uncertainty of each criterion can be fully considered, and some defects that may occur when using either method alone can be avoided. The combination of the two methods can make the decision results more accurate and reliable. Aiming at the evaluation index system of station city, this model establishes the evaluation class model based on analytic hierarchy process and entropy weight method, which can improve the decision quality and efficiency of multi-criteria decision making.

2.4. Analytic hierarchy process weight calculation

2.4.1 Establish the hierarchical structure model.

On the basis of in-depth analysis of the problem, the decision-making objectives, factors to be considered and decision-making objects are divided into target layer, criterion layer and scheme layer according to the correlation relationship. The hierarchical model is shown in the following figure 1:

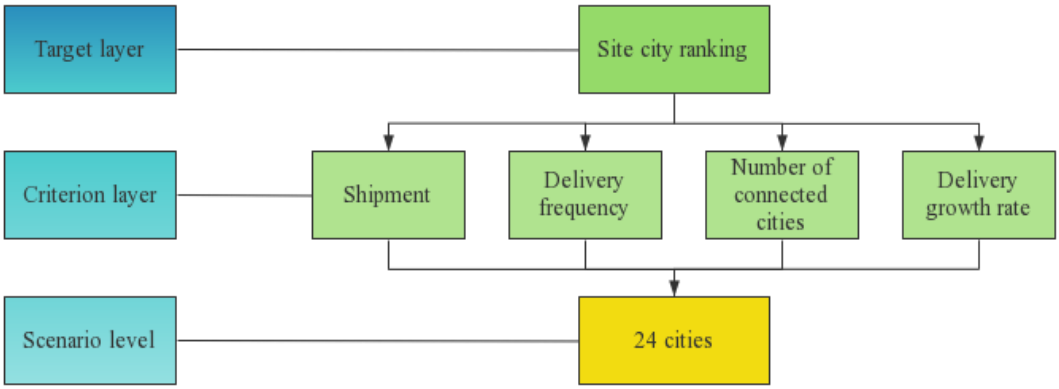

Figure 1 Hierarchy diagram

2.4.2 Judgment matrix construction

We use 9-point scale to determine the judgment criteria and alternatives, and use string diagram (figure 2) to visualize the judgment matrix data:

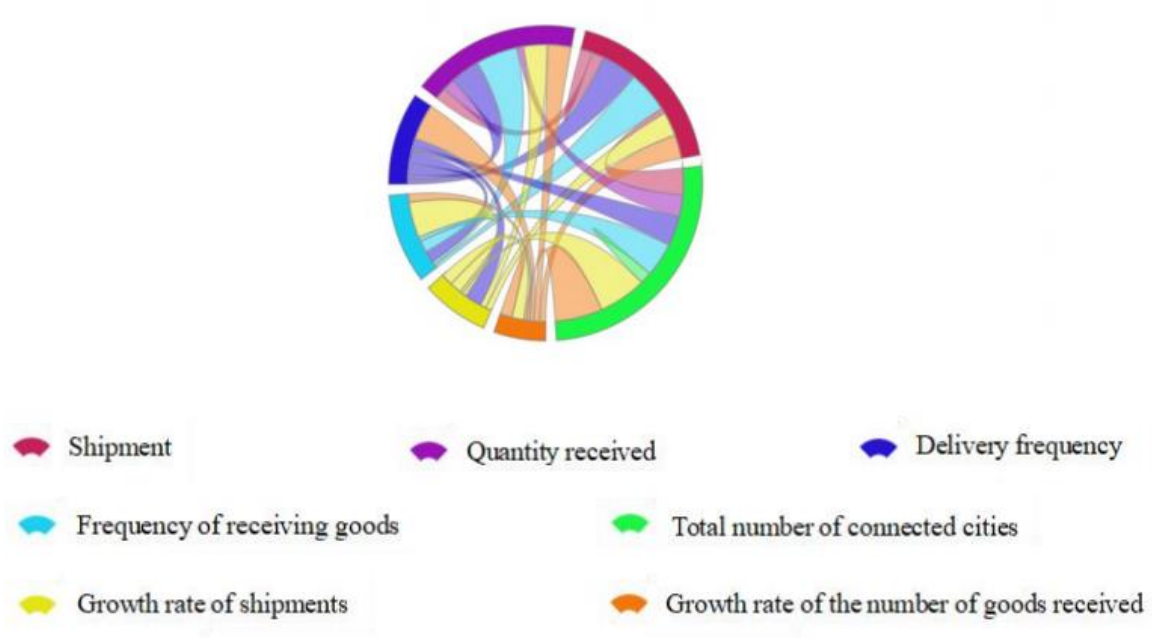

Figure 2 Chordal diagram

2.4.3 Three methods are used to find the comprehensive weight

Because analytic hierarchy process relies on evaluation matrix, it has strong subjectivity.In order to make the results objective, we use arithmetic average method, geometric average method and eigenvalue method to obtain three groups of weights, and find the average value of each index weight to reduce the error and enhance the accuracy and feasibility.

The weight vector of analytic hierarchy process is obtained by synthesizing the weights obtained by the three methods, as shown in figure 3:

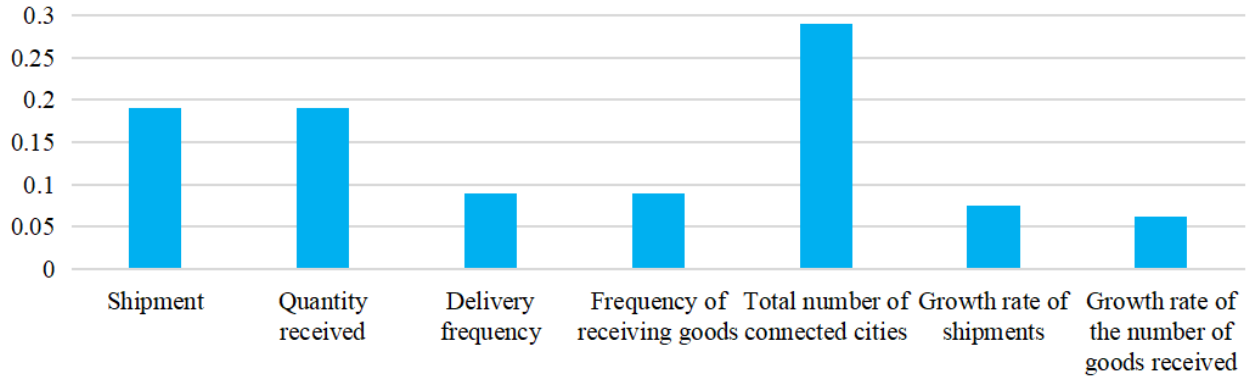

Figure 3 Analytic hierarchy process weight

The calculated consistency ratio CR is 0.0496<0.1, so it can be considered that the consistency of the judgment matrix is good.

2.5. The entropy weight method determines the weight.

2.5.1 Defining evaluation matrix.

Construct an evaluation matrix: there is $A = \{A_1, A_2, \dots, A_n\}$ sample of cities, including $B = \{B_1, B_2, \dots, B_n\}$ evaluation index. The corresponding index value is $x_{ij}(i = 1,2, \dots, n; j = 1,2, \dots, m)$, the evaluation matrix is $C = (x_{ij})_{n\times m}$.

2.5.2 Data standardization processing

Because the value of the attribute value of different indicators is very different, it is necessary to standardize the data in order to be intuitive and easy to evaluate.After standardization, a new evaluation matrix $F = (x_{ij})_{n\times m}$ is obtained.

By substituting the data of each city, the weights of each index obtained by using the entropy weight method are obtained, as shown in the figure 4 below:

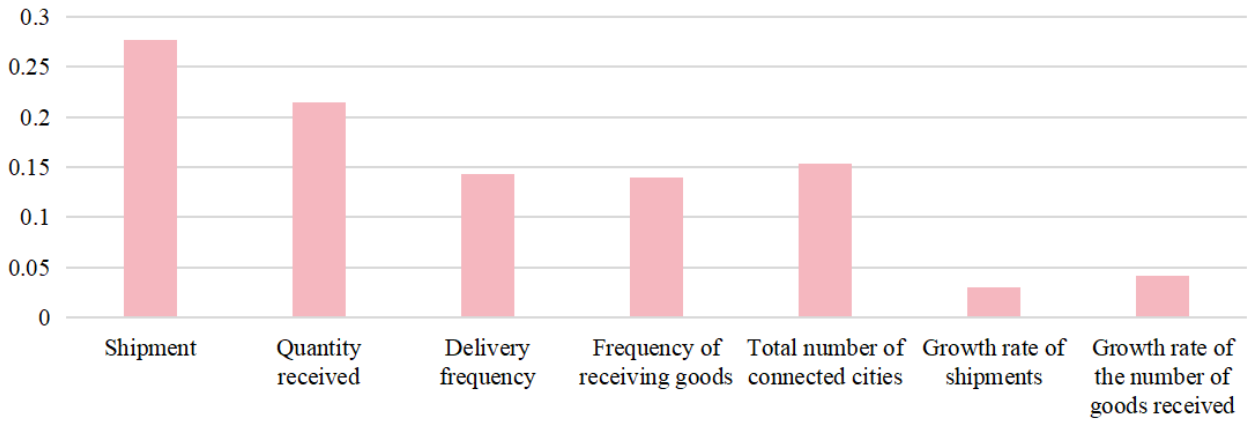

Figure 4 Entropy weight method weight

2.6. The weight of synthetic index is calculated by Lagrange multiplier method

The purpose of combinatorial weight calculation is to integrate the index weights obtained by AHP and entropy weight method.According to the principle of minimum relative information entropy, the Lagrange multiplier method is used to calculate the combined weights. The calculation formula (1) is as follows:

$$W_j = \frac{\sqrt{\alpha_j \beta_j}}{\sum_{j=1}^{n} \sqrt{\alpha_j \beta_j}} \tag{1}$$

In the formula, α_j is the weight calculated by subjective weighted analytic hierarchy process, while β_j is the weight calculated by objective weighted entropy weight method.

The comprehensive weight is shown in the figure 5 below:

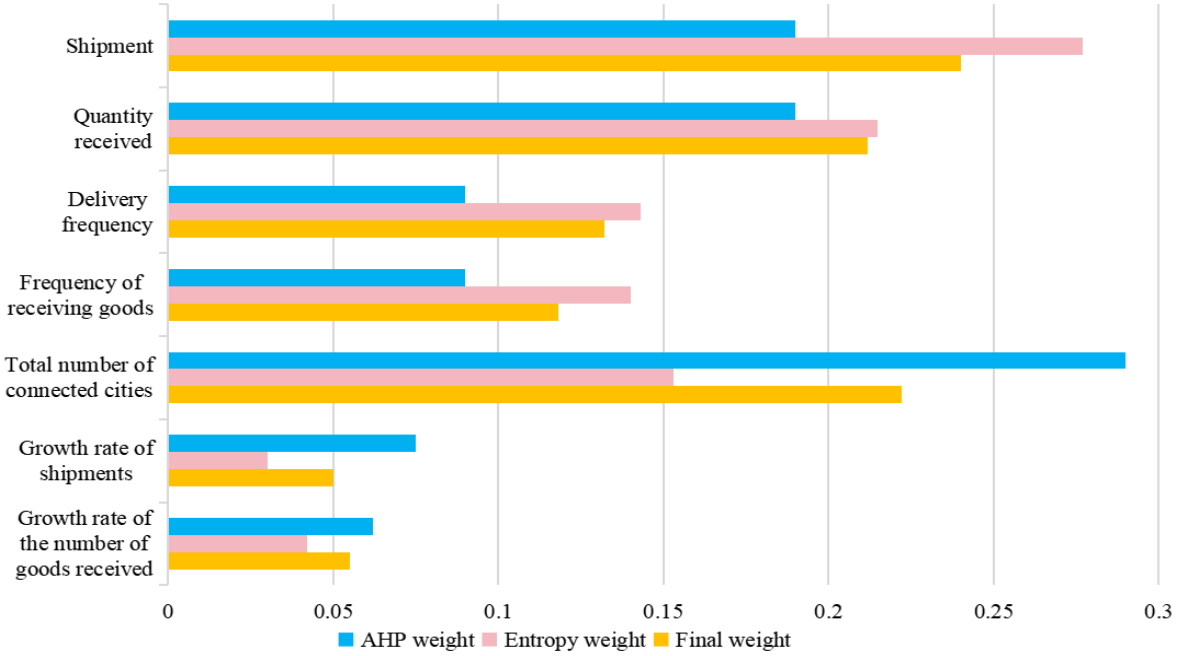

Figure 5 Comprehensive weight

2.7. Evaluation model solving

Based on the comprehensive weights obtained by the above model, the indexes of 24 cities were substituted to obtain the comprehensive ranking of the importance of cities at each site, as shown in figure 6 and table 2, and the results were filled in table 1.

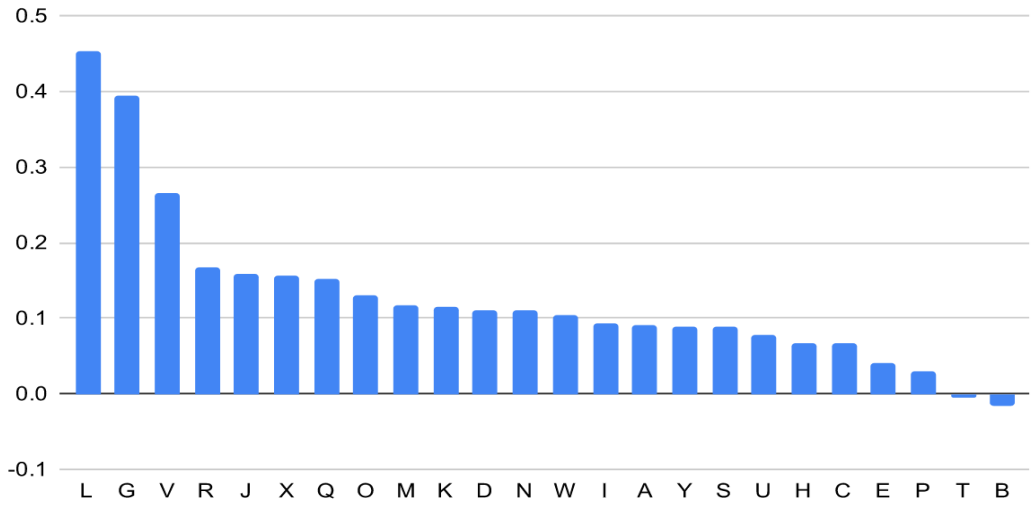

Figure 6 scores and rankings by city

Table 2 Evaluation model results

Sort	1	2	3	4	5
City	L	G	V	R	J

3. Establishment and solution of prediction model

3.1. Selection and establishment of prediction model

Considering that the quantity of express delivery varies greatly and irregularly, we choose ARIMA time series analysis model after considering many prediction algorithms such as exponential smoothing model and weighted moving average model.

3.2. Parameters of ARIMA time series analysis model were selected

ARIMA time series analysis model parameters can be determined based on the following methods:
(1) Determine the difference number
(2) Select the autoregressive (AR) order
(3) select the moving average (MA) order
(4) determine the seasonal order

According to the above principles and using ACF and PACF images (figure 7) to analyze autocorrelation and partial autocorrelation of time series data, the parameters of ARIMA model are determined as (2,1,2):

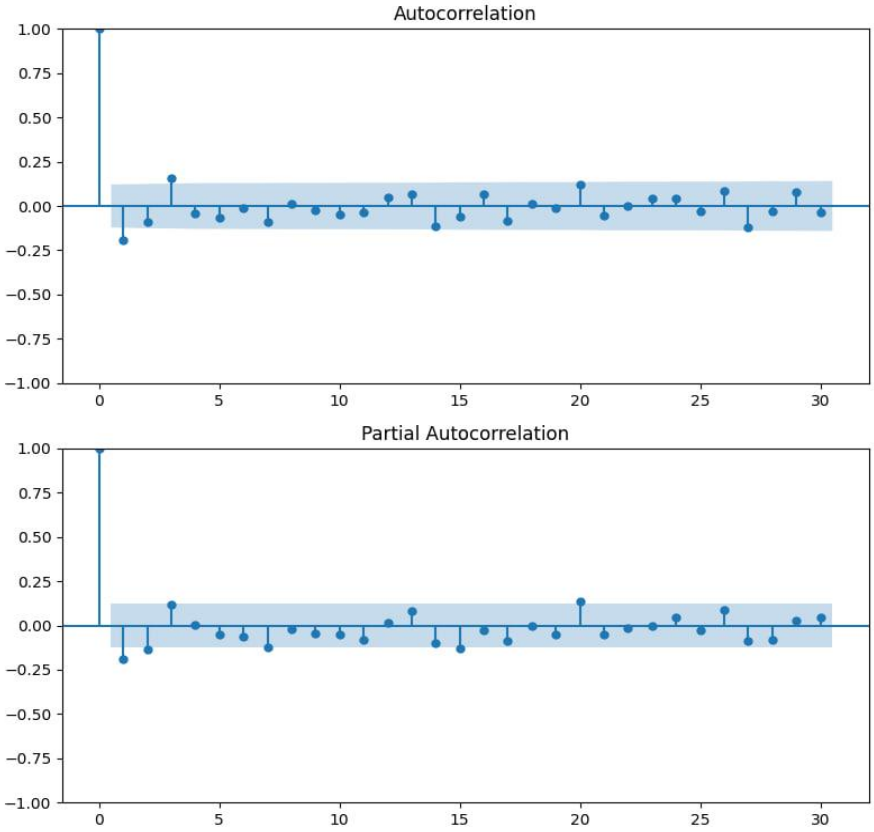

Figure 7 ACF and PACF images

Specifically, (2,1,2) indicates that the auto-regressive order of the ARIMA model is 2, the difference order is 1, and the moving average order is 2, which can fully capture the autocorrelation and random noise in the time series data, and the differential operation can transform non-stationary series into stationary series, improving the prediction accuracy of the model.In addition, this parameter selection is relatively simple, easy to understand and implement, avoiding overfitting of complex models and other problems, and can effectively predict future data trends.

3.3. Solution of prediction model

The pre-processed data is brought into the ARIMA time series analysis model, and the determined ARIMA model is used for fitting. The prediction results of the number of express transportations between cities of each "delivery-receive" station are shown in the table 3 below:

Table 3 Predictive model results

The number of express shipments between "Shipping - Receiving" cities		The total number of express shipments between all "delivery-receive" cities
M-U	152.6461	10589.06
Q-V	46.31690881	
K-L	65.45026719	
G-V	608.1783128	
V-G	557.7023525	10322.33
A-Q	135.2212396	
D-A	43.59066039	
L-K	277.3378702	

4. Conclusion

4.1. Model evaluation

(1) In the evaluation model, we combine analytic hierarchy process and entropy weight method. Firstly, the AHP method is used to decompose the decision problem and determine the weights among the indicators at each level. Then, EWM method is used to calculate the weight of the specific values of indicators at each level to obtain the weight value of each indicator. In this way, we can comprehensively consider the relationship between the importance of indicators and specific values, so as to obtain more accurate decision results.

(2) In the prediction model, we set the parameters of the ARIMA time series prediction model to (2,1,2), which can well capture the trend and periodic changes in the time series, and predict the future trend, with high prediction accuracy; At the same time, it has good robustness for outliers and outliers in the data, which can reduce the impact of these data on the model.

4.2. Model extension

At present, the comprehensive evaluation model established in this paper has certain popularization value. The comprehensive evaluation model established in this paper can better evaluate the comprehensive ability of a station, and the prediction model can accurately predict the demand trend of express delivery, which has certain reference value for the express delivery industry.

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