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# Joint principal component analysis and BP neural network to measure the development level of modern logistics in China

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***Abstract:*** *This article first constructs an evaluation index system for the level of modern logistics development. Then, the principal component comprehensive evaluation method was used to calculate the modern logistics development level of 8 countries, and the weights of each indicator were determined using BP neural network. Finally, a comprehensive comparison was made between the development levels of modern logistics in 8 countries. Through comparison, it is found that: firstly, although there is a gap in the development level of modern logistics in China compared to Japan, this gap is gradually narrowing, with the smallest gap between China and Japan in 2019. Secondly, China's modern logistics development level is higher than that of the United States, and the gap with China is showing a trend of increasing year by year.*

***Keywords:*** *Development Level of Logistics, Evaluation Index System, Principal Component Comprehensive Evaluation Method, BP Neural Network*

## 1. Introduction

Logistics refers to a process that aims to facilitate the flow of physical goods and information from supply to consumption in order to meet the needs of customers [1].

Modern logistics refers to the use of advanced technology and effective integrated management to digitize and intelligentize logistics operations, meet customer needs to a greater extent, and provide better services to customers at a more economical cost.

The level of logistics development refers to the scale of a country's logistics industry, technological level, service level and market demand, reflecting the modern level and development potential of a country's logistics industry.

## 2. The basic principle of principal component comprehensive evaluation method

Principal component analysis, abbreviated as PCA, is a statistical method that converts a set of variables that may be correlated into another set of variables that are linearly uncorrelated through orthogonal transformation. The transformed set of variables is called principal component analysis.

The principal component comprehensive evaluation method is an application of principal component analysis, which uses the idea of dimensionality reduction to transform multiple indicators into several principal components. The variance contribution rate of these principal components is relatively large, which can represent the vast majority of information in the original indicators, ensuring that the number of indicators is reduced without affecting the accuracy of the research.

If the study of a certain thing involves n variables, several principal components can be highly summarized from these n variables. At this point, these n variables can be linearly combined to obtain n principal components, namely

$$\begin{cases} Y_1 = a_{11}X_1 + a_{12}X_2 + \cdots a_{1n}X_n \\ Y_2 = a_{21}X_1 + a_{22}X_2 + \cdots a_{2n}X_n \\ \vdots \\ Y_n = a_{n1}X_1 + a_{n2}X_2 + \cdots a_{nn}X_n \end{cases} \tag{1}$$

Among them, $X_i$ is the i-th variable and $Y_i$ is the i-th principal component.

The criterion for determining the importance of principal components is that if the variance of a principal component is larger, it carries more information and has a greater impact on things, indicating that the principal component is more important.

One of the purposes of conducting principal component analysis is to reduce the number of variables, so generally n principal components are not taken, but m principal components are taken. As for how many suitable principal components are taken for m, it is necessary to choose based on variance. Generally, it is advisable to take a variance contribution rate of more than 85%, that is

$$\frac{\sum_{i=1}^{m} VCR_i}{\sum_{i=1}^{n} VCR_i} \geq 85\% \tag{2}$$

Where, $VCR_i$ is the variance contribution of the i-th principal component.

The steps to comprehensively evaluate things using principal components are as follows.

Step 1: Calculate the characteristic roots and variance contribution rates of each principal component, arrange them in descending order, and select the principal components with a cumulative variance contribution rate greater than or equal to 85%.

Step 2: Calculate the scores of the selected principal component factors.

Step 3: Calculate the scores of the selected principal components.

Step 4: Calculate the comprehensive score of things.

Step 5: Based on the comprehensive score, things can be evaluated, and the higher the comprehensive score, the better the thing.

## 3. The basic principles of BP neural networks

A network composed of multiple neurons is called a neural network, which generally adopts a three-layer structure, namely input layer, hidden layer, and output layer. The neural network structure is shown in Figure 1.

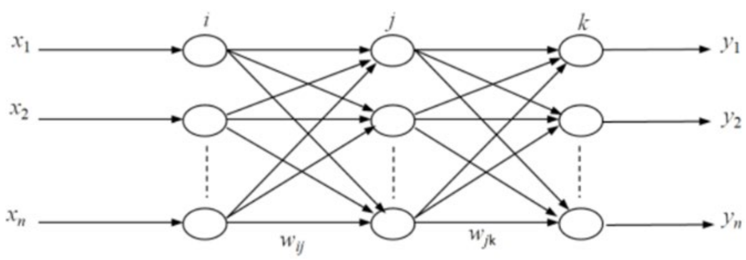


*Figure 1: Neural network structure diagram*

The BP algorithm is an algorithm that allows neurons to automatically adjust weights and thresholds, and the neural network that uses the BP algorithm is called the BP neural network.

The training process of BP neural network can be divided into the following three steps.

Step 1: Select M samples as the training set, randomly determine the initial weight matrix and

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threshold matrix.

Step 2: Calculate the output value using the sample and compare it with the true value to obtain the error.

Step 3: Using error backpropagation, update the weights and thresholds of each layer until the error reaches a local minimum or training meets other conditions.

## 4. Construction of an evaluation index system for the development level of modern logistics

This article establishes an evaluation index system for the development level of modern logistics from four aspects: logistics transportation capacity, green logistics, logistics economic benefits, and logistics information technology [2-5]. The specific evaluation index system is shown in Table 1.

*Table 1: Evaluation index system for the development level of modern logistics*

| Primary indicator | Secondary indicator |
|---|---|
| Logistics transportation capacity | High density |
| | Railway density |
| | Road Density |
| Green logistics | Unit logistics carbon emissions<br>Unit logistics transportation energy consumption<br>The proportion of public water transportation volume<br>The proportion of multimodal transportation volume |
| Logistics economic benefits | Logistics cost per unit GDP<br>Value added of logistics industry per unit GDP |
| Logistics information technology | Unit GDP Automated Warehouse Scale<br>Quantity of logistics information technology |

## 5. Calculation of the development level of modern logistics

Based on the constructed indicator system and the calculation steps of comprehensive scores, the modern logistics development levels of 8 countries including China, America, Japan, Russia, Canada, Thailand, Mexico and South Africa were calculated. The results are shown in Table 2.

*Table 2: Development level of modern logistics*

| Country | Year | Value | Country | Year | Value |
|---|---|---|---|---|---|
| China | 2017 | 0.4028 | Canada | 2017 | -0.6497 |
| China | 2018 | 0.5363 | Canada | 2018 | -0.5701 |
| China | 2019 | 0.682 | Canada | 2019 | -0.5761 |
| China | 2020 | 0.8853 | Canada | 2020 | -0.5407 |
| China | 2021 | 0.9338 | Canada | 2021 | -0.4534 |
| America | 2017 | 0.2936 | Thailand | 2017 | -0.4582 |
| America | 2018 | 0.3132 | Thailand | 2018 | -0.4337 |
| America | 2019 | 0.3969 | Thailand | 2019 | -0.3352 |
| America | 2020 | 0.5104 | Thailand | 2020 | -0.2294 |
| America | 2021 | 0.5152 | Thailand | 2021 | -0.14 |
| Japan | 2017 | 1.3718 | Mexico | 2017 | -0.3886 |
| Japan | 2018 | 1.3969 | Mexico | 2018 | -0.2239 |
| Japan | 2019 | 1.3947 | Mexico | 2019 | 0.0331 |
| Japan | 2020 | 1.6546 | Mexico | 2020 | 0.0297 |
| Japan | 2021 | 1.6800 | Mexico | 2021 | 0.0561 |
| Russia | 2017 | -0.085 | South Africa | 2017 | -1.7242 |
| Russia | 2018 | -0.0922 | South Africa | 2018 | -1.5708 |
| Russia | 2019 | -0.0547 | South Africa | 2019 | -1.5335 |
| Russia | 2020 | -0.05 | South Africa | 2020 | -1.5339 |
| Russia | 2021 | -0.0537 | South Africa | 2021 | -1.3892 |

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## 6. BP neural network determines the weights of each indicator

Divide the 11 indicator data and comprehensive scores from 8 countries from 2017 to 2021 into training and testing sets. Among them, the indicator data and comprehensive scores from 2017 to 2020 are the training set, with a total of 32 samples, the indicator data and comprehensive score for 2021 are the test set, consisting of 8 samples.

Taking the number of hidden layer nodes in the BP neural network from 2 to 18 in sequence, the BP neural network is trained 200 times for each node in the hidden layer, and the average of these 200 output values is used as the final output value. A total of 17 BP neural network groups can be trained. Applying these 17 BP neural network groups to the test set, their MAE and MAPE can be calculated, and the results are shown in Table 3.

*Table 3: MAE and MAPE*

| Nodes | MAE | MAPE (%) | Nodes | MAE | MAPE(%) |
|---|---|---|---|---|---|
| 2 | 0.0213 | 3.3524 | 11 | 0.0487 | 10.0650 |
| 3 | 0.0234 | 4.3459 | 12 | 0.0402 | 5.53651 |
| 4 | 0.0349 | 4.9244 | 13 | 0.0440 | 13.3950 |
| 5 | 0.0341 | 6.5111 | 14 | 0.0454 | 9.4206 |
| 6 | 0.0525 | 10.078 | 15 | 0.0398 | 8.1016 |
| 7 | 0.0425 | 6.6211 | 16 | 0.0497 | 9.5778 |
| 8 | 0.0461 | 8.8150 | 17 | 0.0908 | 12.2505 |
| 9 | 0.0545 | 9.1457 | 18 | 0.0444 | 9.4793 |
| 10 | 0.0432 | 4.9750 | | | |

From Table 3, it can be seen that the BP neural network group with 2 hidden layer nodes has the smallest MAE and MAPE, making it the optimal BP neural network group.

Furthermore, the weights of the 11 indicators determined by the optimal BP neural network group can be calculated, and the weights of the primary indicators can be obtained through the weights of the secondary indicators, as shown in Table 4.

*Table 4: Weights of primary indicators and secondary indicators*

<table>
<tr><th>Primary indicator</th><th>weight</th><th>Secondary indicator</th><th>weight</th></tr>
<tr><td rowspan="3">Logistics transportation capacity</td><td rowspan="3">0.2566</td><td>High density</td><td>0.1221</td></tr>
<tr><td>Railway density</td><td>0.0975</td></tr>
<tr><td>Road Density</td><td>0.0370</td></tr>
<tr><td rowspan="4">Green logistics</td><td rowspan="4">0.3665</td><td>Unit logistics carbon emissions</td><td>0.1255</td></tr>
<tr><td>Unit logistics transportation energy consumption</td><td>0.1508</td></tr>
<tr><td>The proportion of public water transportation volume</td><td>0.0487</td></tr>
<tr><td>The proportion of multimodal transportation volume</td><td>0.0415</td></tr>
<tr><td rowspan="2">Logistics economic benefits</td><td rowspan="2">0.1472</td><td>Logistics cost per unit GDP</td><td>0.0283</td></tr>
<tr><td>Value added of logistics industry per unit GDP</td><td>0.1189</td></tr>
<tr><td rowspan="2">Logistics information technology</td><td rowspan="2">0.2297</td><td>Unit GDP Automated Warehouse Scale</td><td>0.1319</td></tr>
<tr><td>Quantity of logistics information technology</td><td>0.0978</td></tr>
</table>

## 7. Conclusions

In order to facilitate the observation of the trend of modern logistics development in various countries from 2017 to 2021, it can be plotted as a line chart, as shown in Figure 2.

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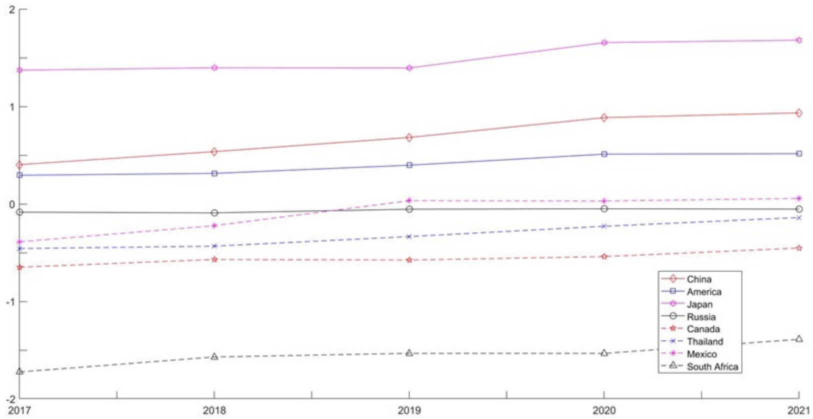


*Figure 2: Development level of modern logistics in various countries*

From Figure 2, the following three points can be seen.

(1) From 2017 to 2021, the development level of modern logistics in China has shown a trend of increasing year by year, and it ranks high and second among eight countries.

(2) Although there is a gap in the development level of modern logistics in China compared to Japan, this gap is gradually decreasing, and the gap with Japan was the smallest in 2019.

(3) The development level of modern logistics in China is higher than that in the United States, and the gap between the United States and China is showing an increasing trend year by year.

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