Research on Railway Logistics Resources Optimization Theory

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ABSTRACT: In the increasingly competitive logistics market, it is very important to scientifically, effectively and objectively evaluate the validity of integration optimization of the railway logistics resources and the core of logistics enterprises. Supported by the multidisciplinary theory, based on the method combined with theory and practice, this paper uses BP neural network algorithm to conduct empirical analysis of the core capability of China’s railway logistics enterprises, and uses AHP method to prove the accuracy of results and obtain a conclusion that the core competition of China’s railway is increasingly enhanced, thus providing a theoretical and practical reference for the development of China’s railway logistics.

Keywords: railway logistics system; integration optimization; BP neural network algorithm; application

1 RESEARCH BACKGROUND

With the continuous improvement of China’s social economy and people’s living standard, the demand for social production and living material consumption is increasingly strong, greatly promoting the development of China’s logistics market. China has promoted the development of the logistics industry to the height of the national strategy, and has issued a number of outline planning, and has made a major adjustment on the Medium and Long-term Railway Network Planning introduced in 2004, which has increased the original total investment of 1.5 trillion to 5 trillion. Research and practice show that, the integration of logistics resources is the most direct and effective way to transform the transportation industry into modern logistics. Therefore, the integration optimization of railway system resources and transformation into modern logistics has become an inevitable choice for future railway development.

How to effectively integrate the internal and external logistics resources of the system and enhance its core capability to meet changing demands of external logistics for the railway will face a series of deep problems, which is summarized as follows: (1) a problem in the transformation of integration optimization of railway logistics resources, that is, transformation from the extensional integration manner of original large investment and large consumption into a model of connotational integration of railway logistics resources on the basis of extensional integration; (2) a flexible problem in the integration optimization of railway logistics resources, that is, to get rid of constraint of the traditional railway management concept and keep up with the rapid pace of development of modern logistics; (3) a problem in the evaluation of integration optimization effect of railway logistics resources, that is, to use a set of systematic evaluation system to monitor and evaluate the integration process.

The core of the above problems in the integration optimization is as follows: the integration optimization of railway logistics resources to transform into modern logistics requires systematic theoretical guidance. This paper will monitor and evaluate the integration process from the evaluation system of the integration

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optimization effect of railway logistics resources, thus providing a theoretical and practical reference for the development of China’s railway logistics.

2 OVERVIEW OF RELEVANT RESEARCH

In recent years, domestic and foreign scholars have paid more and more attention on the integration of logistics resources, and reflected their own characteristics. Toshko Z., et al. \(^1\) proposed an idea of integration of logistics resources with the purpose of enhancing logistics capacity. Jmes K.H. \(^2\) used Markovian decision process to research the integration of shippers as central logistics resources providers. Ho W. \(^3\) applied for AHP/GP comprehensive model constructed in organic combination with AHP method and GP and combined with LINDO calculation software into logistics distribution network for integration analysis, obtaining a satisfactory integration scheme. Fiedler C.J \(^4\) established a logistics resource integration model based on Petri network. The research features of integration optimization of foreign logistics resources are as follows: 1) it is focused on the basic theoretical research of integration optimization of logistics resources; 2) it is focused on the analysis technology research of integration optimization of logistics resources. At present, the theoretical research and practice of integration optimization of China’s logistics resources are in the initial stage, which still have a considerable gap compared with the foreign advanced level. The shortcomings in the research of integration optimization of domestic logistics resources are summarized as follows: 1) it is lack of comprehensiveness and integrality; 2) the feasibility of theoretical research is not strong; 3) the phenomenon of theory in the field of logistics lagging behind the practice is very prominent.

In terms of evaluation of logistics resource integration, the difference is mainly reflected in the selection of evaluation methods and design of evaluation index system and so on. Wang Ying, Sun Linyan, et al. \(^5\) combined with EDA and AHP algorithms to establish a two-stage evaluation model. Wang Ying, et al. \(^6\) applied EDA method to comprehensively evaluate the characteristic attributes of the third-party logistics service provider. Chen Shunzheng, Song Guofang, et al. \(^7\) used DEA sensitivity analysis model. Xu Xinqing, Cheng Junmo, et al. \(^8\) used the neural network method. Chen Ke, Li Hua \(^9\) used the improved gray multi hierarchical comprehensive evaluation and analysis methods to respectively provide solutions to the problem in selecting evaluation of the third-party logistics service providers. Wang Chuanxu \(^10\) used the multi-objective mixed integer programming model to optimize the cargo between the shipper and the carrier in the transport service supply chain.

3 RESEARCH METHODS

The evaluation system of integration optimization effect of railway logistics resources is an important part of the integration optimization theory of railway logistics resources, which includes the evaluation of validity of integration optimization of the railway logistics resources and evaluation of overall integration effect of railway logistics resources.

3.1 Evaluation of validity of integration optimization of railway logistics resources

3.1.1 Validity and types of integration optimization of railway logistics resources

(1) Concept of validity of integration optimization of railway logistics resources

The related concept of DEA validity is used to define the validity of integration optimization of railway logistics resources. Fractional programming form of DEA model is as follows:

$$\max h_0 = \frac{U^T Y_0}{V^T X_0}$$
$$s.t. \frac{U^T Y_j}{V^T X_j} \leq 1$$
$$U \geq 0; V \geq 0; j = 1, 2, ..., n;$$

The programming undergoes Charnes-Cooper linear transformation and dual transformation, obtaining a formula (2):

$$\min h$$
$$\sum_{j=1}^{n} x_j \lambda_j + S^- = h x_0$$
$$\sum_{j=1}^{n} y_j \lambda_j - S^+ = y_0$$
$$\delta \sum_{j=1}^{n} \lambda_j = \delta$$
$$\lambda_j \geq 0; S^- \geq 0; S^+ \geq 0; \delta = 0 \text{ or } 1; j = 1, 2, ... n;$$

When $\delta=0$, formula (2) is C^2R model; when $\delta=1$, formula (2) is C^2GS^2 model. If the objective function of the formula model (2) is 1, then DEA is valid. DEA validity of the evaluation unit $j(DMU)$ includes “technology validity” and “scale validity”. C^2R model is used to determine whether the evaluation unit has technology validity or scale validity, while C^2GS^2 model is used to determine the technology validity of the evaluation unit.

In this paper, the integration coordination validity, integration development validity and integration validity are defined as follows:
1) Integration coordination validity reflects the degree of coordination between various elements within the system and subsystems.[11, 12]

2) Integration development validity = \[
\sum_{j=1}^{n} a_j^0 \] (3)

When the integration development validity is 1, that is, the integration development is valid; when the integration development validity is greater than 1, it indicates that the evaluation unit is in the stage of increasing returns, showing that the development of evaluation unit in this stage gains increasing returns, and there is a need to increase input to obtain a greater output; when the integration development validity is smaller than 1, it indicates that the evaluation unit is in the stage of decreasing return to scale, and more investment will not bring more output, showing that the development of evaluation unit in this stage gets decreasing returns, and there is a need to take further effective integration measures.

3) Integration validity = integration coordination validity \times integration development validity

(2) Types of validity of integration optimization of railway logistics system

For the railway logistics system, if the numerator and denominator of the fractional formula (1) are the input and output combinations of the railway logistics system, the validity of railway logistics resource integration of \( C^2 R \) model in this system can be calculated. Similarly, the integration validity in the railway logistics system is a sufficient and necessary condition for the establishment of integration coordination validity in the railway logistics system and integration development validity in the railway logistics system. The integration coordination validity in the railway logistics system and integration development validity in the railway logistics system reflect the coordination and development status of the internal elements of the railway logistics system after integration optimization of the logistics resources.

If the numerator and denominator of the fractional formula (1) are the ratio of the input combination of logistics systems in a railway bureau or a company to the output combination of logistics systems in another railway bureau, the validity calculated based on \( C^2 R \) model is the integration validity of the logistics systems in the railway bureau or the company. The integration validity of the logistics systems in the railway bureau or the company indicates that the integration coordination validity of the logistics systems in a railway bureau and the integration development validity of the logistics systems in a railway bureau coexist. The integration coordination validity of the systems and the integration development validity of the systems reflect the coordination and development conditions of the railway logistics system.

The numerator and denominator of the fractional formula (1) are replaced by a railway logistics system and other logistics systems (roads, waterways and airways), which can be a reflection of the coordination and development status of the internal and external system after integration.

3.1.2 Evaluation of validity of integration optimization of internal logistics resources in the railway logistics system

The evaluation of validity of integration optimization of internal logistics resources in the railway logistics system can be analyzed from the following two aspects: first, timing sequence is selected as a decision-making unit to calculate the validity of integration optimization of the railway logistics system resources in each year; second, each railway bureau is selected as an evaluation decision-making unit to calculate the validity of logistics resources integrated by each railway bureau in the railway logistics system.[14]

The index system reflecting the validity of integration optimization of the railway logistics system resources should follow the basic principle set in the above index system, and can comprehensively reflect the common characteristics of integration optimization of logistics resources of the railway or the railway bureau, and have a certain factor index oriented by the development of railway freight logistics as an input and output index system.

In terms of the evaluation model, according to the above related concepts, the integration validity of railway logistics system resources is equal to a product of its integration coordination validity and integration development validity. The integration coordination validity means that the model \( C^2 GS^3 \) is valid. Thus, the coordination validity of integration optimization of railway logistics system is solved through the programming model (2) and \( \sigma=1 \); the integration development validity is solved through the programming model (2) (\( \sigma=0 \)) and formula (3).

3.2 Evaluation of core competitiveness of railway logistics system

3.2.1 Selection of evaluation methods

To take the initiative in the market competition, the key for the railway logistics enterprise system lies in the accurate positioning and timely improvement of the core capability of enterprise. Therefore, it is of great significance to scientifically, effectively and objectively evaluate the core capability of railway logistics enterprises, and accurately locate the core capability of enterprises in the same industry and acquire sustainable competitiveness. There are many common methods to evaluate the core competitiveness of enterprises, including DEA evaluation method, fuzzy comprehensive evaluation method, gray correlation analysis method, cluster analysis method and artificial neural network evaluation method and so on.

3
In this paper, BP neural network algorithm is used for comprehensive evaluation of the core competitiveness of railway logistics, mainly because of the characteristics of a strong fitting ability of neural network for nonlinear function.

3.2.2 Neural network evaluation modeling

(1) Neural network model

Multi-hierarchical artificial neural network is currently the most widely used artificial neural network. This network adopts error back propagation learning algorithm, which is called as BP network. The learning of network consists of four processes: a “model propagation” process of the learning mode transmitted from the input layer to the output layer through middle layer; an error back propagation process of the error signal between the expected output of the network and the actual output gradually amending the connection weight from the output layer to the input layer through middle layer; a memory training process formed by repeated alternation of the “model propagation” and “model back propagation”; a “learning proficiency” process of overall error of the network tending to be a minimal value [15].

In this paper, a multi-input single-output three-layer neural network is used as the system evaluation model, as shown in Figure 1.

![Three-layer neural network structure](image)

In Figure 1, n and m respectively represent the number of input node and hidden node; \(U_{p1}, U_{p2}, ..., U_{pn}\) are the evaluation index values of the p-th sample model in the evaluation index domain \(X = \{x_1, x_2, ..., x_n\}\), recorded as:

\[U_p = \{U_{p1}, U_{p2}, ..., U_{pn}\}\]

\(h\)-th sample model constitutes the sample matrix:

\[U = \{U_1, U_2, ..., U_n\}^T = \{U_{pj}\}_{n \times p}\]

\(r_{p1}, r_{p2}, ..., r_{pn}\) are the evaluation vectors of \(U_p\) on \(X\) after quantification by the normalized converter, recorded as:

\[\bar{r}_p = \{r_{p1}, r_{p2}, ..., r_{pn}\}\]

\(w_j(k=1,2,...,m)\) is the connection weight from the \(j\)-th node of the input layer to the \(k\)-th node of the hidden layer; \(y_{pk}(k=1,2,...,m)\) is the output of the \(k\)-th node of the hidden layer for the sample mode \(p\); \(b_p\) is the output of the sample mode \(p\).

(2) Normalized converter of evaluation index

The evaluation index generally has the following types based on its attributes, such as the cost type, benefit type, moderate type and interval type. For \(n\) indicators in \(X\), assuming that the value range of the \(j\)-th index \((x_j)\) is \(d_j = [\min x_j, \max x_j]\) \((j=1,2,...,n)\), defining that \(r_{pj} = U_{dj}(y_{pj})\) \((j=1,2,...,p)\) is the standardized value of the index value \(x_{pj}\) for the evaluation index \(x_j\) of the sample mode \(p\), and \(r_{pj} \in [0,1]\), of which \(U_{dj}(\cdot)\) is a standardized transfer function of the index \(x_j\) defined in \(d_j\) the standardized transfer function of these three types of indexes is as follows:

Assuming that \(a_j\) is the maximum value of the \(j\)-th index; \(\min x_{pj} = b_j\), \(b_j\) is the minimum value of the \(j\)-th index.

1) For the benefit type of index, that is, the greater the index value, the better:

\[r_{pj} = \frac{x_{pj} - b_j}{a_j - b_j}\]  (4)

2) For the cost type of index, that is, the smaller the index value, the better:

\[r_{pj} = \frac{a_j - x_{pj}}{a_j - b_j}\]  (5)

3) For the moderate type of index, that is, the index value stabilizing at a fixed value is the best index:

\[r_{pj} = \frac{1}{1 + [q - x_{pj}]}\]  (6)

Where: \(q\) is the most appropriate value for the index

4) For the interval type of index, that is, the index value in a certain interval is the best index:

\[r_{pj} = \begin{cases} 
1 - \frac{q_1 - x_{pj}}{\max(q_1 - b_j, a_j - q_2)} & \text{if } x_{pj} < q_1 \\
1 - \frac{x_{pj} - q_2}{\max(q_1 - b_j, a_j - q_2)} & \text{if } x_{pj} > q_2 \\
1 & \text{otherwise}
\end{cases}\]  (7)

Where: \([q_1, q_2]\) is the best stable interval of the index.

The index normalization matrix can be obtained through the above calculation:

\[R = \left[\begin{array}{c}
r_1 \\
r_2 \\
r_n \\
\end{array}\right] = \left[\begin{array}{c}
r_{pj} \\
r_{pj} \\
r_{pj} \\
\end{array}\right]_{n \times p}, r \in [0,1]\]
(3) Implementation of BP neural network algorithm

The Sigmoid function is used to describe the nonlinear relationship between the output and the input of each node in BP neural network in Figure 1, that is,

\[ f(x) = \left[1 + \exp(-x)\right]^{-1} \tag{8} \]

In the formula (8), \( x \) takes continuous values in \((0, 1)\).

The determination of the unit number of hidden layer is directly related to the number of input and output units. Too little units of hidden layer, it is impossible to train the network and identify samples that have not been seen previously, with a poor fault tolerance; with too many units of hidden layer, and too long learning time, error may not be significantly reduced. Under normal circumstances, to calculate based on the following empirical formula:

\[ n_{H} = \sqrt{n_{i} + n_{0} + l} \tag{9} \]

Where: \( n_{H} \) is the number of neurons in the hidden layer; \( n_{i} \) is the number of neurons in the input layer; \( n_{0} \) is the number of neurons in the output layer; \( l \) takes an integer between 1 and 10.

The output of the sample mode in the hidden layer is calculated based on the following formula:

\[ y_{pk} = f\left(\sum_{j=1}^{n} w_{j} r_{pj} - \theta_{k}\right) \quad k = 1, 2, ..., m \tag{10} \]

Where: \( \theta_{k} \) represents the offset value of the node \( k \) in the hidden layer.

The output of the sample mode \( p \) in the output layer is calculated based on the following formula:

\[ b_{p}^{*} = f\left(\sum_{k=1}^{m} w_{k} y_{pk} - \theta\right) \tag{11} \]

Where: \( \theta \) represents the offset value of the node in the output layer.

The learning training of BP network is a process of error back propagation and correction. Define that the total error function of the actual output \( b_{p}^{*} \) and the expected output \( b_{p} \) for \( h \) sample mode(s) is:

\[ E = \frac{1}{h} \sum_{p=1}^{h} \left(b_{p}^{*} - b_{p}\right)^{2} / 2 \tag{12} \]

4 CASE ANALYSIS

In this paper, with the analysis objects of railway logistics operation conditions from 1995 to 2009, BP neural network evaluation model is used for comprehensive evaluation of the core competitiveness of railway logistics system and its changes.

4.1 Index selection and data collection

In order to objectively reflect the changes in the core competitiveness of railway logistics, the quantitative index value is used as an evaluation basis. Integrated with the railway logistics service competitiveness, railway logistics resource integration capability and railway logistics innovative development capability, combined with the above evaluation methods for the validity of railway logistics resource integration, this paper finally determines the indexes used for evaluation of the core competitiveness of the railway logistics: composition of volume of freight transport (%) \((x_{1})\), composition of rotation volume of freight transport (%) \((x_{2})\), safety level of railway freight (number of accidents in running kilometers per million freight locomotives) \((x_{3})\), coordination validity of the railway logistics resource integration \((x_{4})\), development validity \((x_{5})\), comprehensive validity \((x_{6})\), income of freight transport (10 billion) \((x_{7})\), amount of freight of railway coal (100 million tons) \((x_{8})\) and amount of shipment of railway containers (10 million tons) \((x_{9})\), constituting a comprehensive evaluation index set. Its hierarchical structure is shown in Figure 2; the index data is shown in Table 1.

Table 1. Evaluation index of core competitiveness of China’s railway logistics system.

<table>
<thead>
<tr>
<th></th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
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<td>1.0000</td>
<td>1.0000</td>
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<td>6.74</td>
<td>0.28</td>
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<td>1996</td>
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<td>1.74</td>
<td>0.9992</td>
<td>1.2789</td>
<td>1.2779</td>
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<td>7.21</td>
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<td>1997</td>
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<td>0.9823</td>
<td>1.0566</td>
<td>1.0379</td>
<td>4.61</td>
<td>7.03</td>
<td>0.97</td>
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<td>1998</td>
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<td>33.0</td>
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<td>5.03</td>
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<td>1999</td>
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<td>10.10</td>
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<td>0.9825</td>
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<td>1.0573</td>
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<td>0.9737</td>
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<td>1.0834</td>
<td>10.58</td>
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<td>1.0444</td>
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<td>15.99</td>
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<td>1.0048</td>
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<td>1.0000</td>
<td>18.17</td>
<td>17.51</td>
<td>7.17</td>
</tr>
</tbody>
</table>

4.2 Input and output mode pairs of neural network

Before data processing, there is a need to first determine the expected output of the mode pair of the neural network training set. In this paper, AHP method is used to determine the index weight used for evaluating the core competitiveness of the railway logistics system. According to the structural hierarchical relations in the core competitiveness index system of the railway logistics system (Figure 2), the weight of the index relative to the target layer (core competitiveness of the railway logistics system) can be solved by AHP method: \( V = \{v_{1}, v_{2}, ..., v_{9}\} = \{0.10, 0.11, 0.12, 0.12, 0.13, 0.15, 0.09, 0.08, 0.10\} \); the dimensionless method is used to calculate the data in Table 4-1 according to the formula (3) - (7); the comprehensive evaluation scores of the core competitiveness of the railway logistics
system in each year can be obtained through combination with the weight of each index: \( \{b_p, p=1,2,...,15\} = \{0.6016,0.4418,0.6106,0.5881,0.6920,0.7348,0.7440,0.8014,0.7922,0.68126,0.6727,0.7344,0.7373,0.7288\} \), which can be as the expected output of BP network training sample set. Nine index data of the core competitiveness of the railway logistics system after standardization processing and the comprehensive evaluation scores calculated by AHP method to determine the weight form 15 input and output data model pairs of BP neural network.

4.3 Network training and data simulation

The evaluation of the core competitiveness of the railway logistics system by the neural network requires a certain amount of more typical known samples (input and output data model pairs) as the training set to train the neural network, and then a large amount of data can be comprehensively evaluated. Taking into account the characteristics of the timing sequence of samples, the mode with the number of 1 to 10 is selected as a training unit to input BP neural network for training. There are nine neurons in the input layer of BP neural network, and one node in the output layer, that is, the comprehensive evaluation score; four units in the hidden layer are determined by the formula (9), thus constructing a BP neural network with the network structure of 9-4-1. Given that the learning accuracy is \( \epsilon=1e^{-5} \), the learning speed is \( \alpha=0.05 \), the network training function uses \text{traindgm} \) function, AHP of each training unit determines the comprehensive evaluation value of the weight as the expected output; after 25,665 training steps of learning, Matlab Software operation is used to complete network training, with the total error of \( 9.9997e^{-6} \). The learning results are shown in Table 2.

The relative error of each learning sample in Table 2 is small. Combined with BP network training effect in Figure 3 and Table 2, it is found that the learning results of the trained three-layer BP neural network are ideal.

After completion of network training, the trained three-layer BP neural network is used to select the model pairs with the number of 11 to 15 (corresponding to the year of 2005 to 2009) as the test unit input network to detect the network evaluation and prediction accuracy. The data simulation evaluation results are very close to AHP evaluation scores, as shown in Table 3.

According to the test results in Table 3, the comprehensive evaluation results of BP neural network are basically consistent with the comprehensive evaluation results of weight determined by AHP, indicating that the trained BP neural network can be better used to evaluate the core competitiveness of the railway logistics system.
5 CONCLUSION

In this paper, the comprehensive evaluation method of DEA and BP neural network are described in detailed and quantitative manner. The comprehensive evaluation method of AHP and BP neural network is used for comprehensive evaluation of the validity of integration optimization of the railway logistics resources and enhancement of core competitiveness of the railway logistics system, obtaining the following conclusions: 1. BP neural network evaluation method not only overcomes the influence of human factors and fuzzy randomness caused by artificial evaluation and guarantees the accuracy of evaluation results due to its stronger self-organization, self-application and self-learning ability, but also has a stronger dynamic nature. As time progresses and samples increasing, further learning and dynamic tracking can provide an effective evaluation method for the establishment of a comprehensive evaluation system for integration optimization of the railway logistics resources. 2. With the deepening of the integration of logistics resources in China’s railway freight transport, its core competitiveness has been increasing year by year. Meanwhile, there is a need to continue to strengthen constructions efforts in the railway logistics resource integration in the western region, in order to achieve the overall distribution balance of railway logistics resources and obtain a more significant integration effect.

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