Economic Adaptation Grade Evaluation of Integrated Transport System Based on Matter-Element Extension with ANP

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Abstract. Based on the concept of coordinated development between transportation and economy, a set of evaluation index system is constructed from total scale, transportation structure and service level, which is to measure economic adaptability of transport system. Then Matter-Element Extension with ANP algorithm is put forward to calculate the economic adaptation grade of integrated transport system with empirical analysis of Yunnan province, which has verified that this model is applicable.

1. Introduction
The development of transport is closely related to the level of the national economy in this region. A consistent consistency interval of judgment in the decision support system of the Analytic Hierarchy Process (AHP) was proposed [1]. And an indicator system between public transport and economy is established which verified that the two were positively related [2]. Yulong Pei used an improved AHP algorithm to calculate the index weights [3]. Da Zheng applied AHP and entropy weight method to calculate the weight [4]. Yuqi Yang constructed an index system and quantitatively analyzed it based on the information entropy theory [5]. Yuxia Chen proposed 20 indicators and gray correlation model for empirical analysis [6].

Therefore, the research mainly involves the design of evaluation index system, the calculation of weight and evaluation method. It is known from existing research that the proportion of quantitative indicators is insufficient and it also does not consider the interaction between the indicators at the same layer, so this paper designs a more reasonable indicator system and chooses matter-element extension theory with analytic network process (ANP) to determine economic adaptation level of transport system.

2. Matter-Element Extension with ANP Algorithm
In extension theory, Matter-Element can organically combine name, feature and value of objects to transform qualitative concept into quantitative values, which is to calculate the weight parameters of indexes, and then obtain the correlation degree and finally determine the evaluation level. The index weight adopts ANP algorithm, which is a target decision method composed of two clusters, namely the control layer and the network layer, which can reflect the mutual relationship between the elements in the index set. Specific steps of the algorithm are as follows:
Step 1: Taking \( P_s (s = 1, 2, \ldots, m) \) as the criterion, and taking \( e_k (k = 1, 2, \ldots, n_j) \) in \( C_j \) as sub-criteria, the influence of \( e_k \) in \( C_j \) on \( e_k (k = 1, 2, \ldots, n_j) \) is calculated.

Step 2: Eigenvectors are calculated and normalized to obtain the weight vectors, then the hypermatrix \( W \) is calculated.

\[
W = \begin{bmatrix}
W_{11} & W_{12} & \cdots & W_{1N} \\
W_{21} & W_{22} & \cdots & W_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
W_{N1} & W_{N2} & \cdots & W_{NN}
\end{bmatrix}
\]  

(1)

Step 3: Based on \( P_s (s = 1, 2, \ldots, m) \) and the importance of \( C_j (j = 1, 2, \ldots, n_j) \), judge matrix and eigenvector are calculated, and normalized weighted matrix \( A \) is obtained. Hypermatrix \( W \) is weighted calculated, then \( \hat{W}_y \) and limit supermatrix \( W^\infty \) are obtained.

\[
\hat{W}_y = a_y W_y (i = 1, 2, \ldots, N, j = 1, 2, \ldots, N)
\]  

(2)

\[
W^\infty = \lim_{t \to \infty} \hat{W}^t
\]  

(3)

Step 4: To determine rank field \( U \), evaluation index set \( C \), matter-element, and calculate the classical and extension matter elements.

\[
R_j = (U_j, C_j, V_j) = \begin{bmatrix}
U_j & c_1 & \langle a_{j1}, b_{j1} \rangle \\
& c_2 & \langle a_{j2}, b_{j2} \rangle \\
& \vdots & \vdots \\
& c_n & \langle a_{jm}, b_{jm} \rangle
\end{bmatrix}
\]  

(4)

Step 5: With the weight of the secondary index and the correlation degree of adaptive grade, the correlation degree of the primary index can be calculated.

\[
K(c_i) = [w_{i1}, w_{i2}, \ldots, w_{ip}]
\]  

(5)

Step 6: According to the weight of the first-level index and its relevance to the adaptation level, the relevance of the element to be evaluated was calculated.
3. Construction of Index System

This paper designs an index system from three dimensions: total scale, transport structure, and service level. The total scale includes the coordination degree of transport facilities and investment scale and the integrated transport capacity. The combination of industrial structure and internal structure reflects the level of transport structure. The service level includes the level of travel service, management and construction, and safety emergency level. The index elements in each index cluster have dependencies and feedbacks. For example, the intensity of passenger transport is affected by the level of transport network. The specific evaluation index system is shown in Figure 1.

![Figure 1. The hierarchical evaluation index system](image)

4. Results

Based on the above research, the evaluation hierarchy is divided to five grades respectively I, II, III, IV, V. Level I represents the highest level, and level V indicates that transport system and economic system does not match.
Table 1. Rate assessment result

|                        | Level I | Level II | Level III | Level IV | Level V | Level |
|------------------------|---------|----------|-----------|----------|---------|-------|
| Total Scale            | -0.6292 | -0.4513  | 0.14      | 0.1401   | -0.0195 | IV    |
| Transport Structure    | -0.5242 | -0.3996  | -0.22     | -0.0099  | -0.0437 | IV    |
| Service Level          | -0.4875 | -0.3422  | -0.19     | 0.0117   | -0.2032 | IV    |
| Adaptation Grade       | -0.56335| -0.4102  | -0.18     | -0.06375 | -0.0679 | IV    |

According to the indicator system of Figure 1, and based on the statistical data of Yunnan Province from 2010 to 2019, all indicators are quantitatively calculated and qualitatively analyzed. The economic adaptation grade of Yunnan Province is calculated as level IV. The specific data is shown in Table 1. Comparing the results of this study with the current situation of Yunnan Province, the evaluation results are more reasonable, which shows that this research method is reliable and effective.

5. Conclusion

Based on the above research, the following conclusions are drawn:

1. The calculation of index weight by replacing AHP with ANP changes the independent hierarchy structure of AHP, which can fully consider the mutual influence of each index factor cluster, whose results are relatively more accurate.

2. Matter-Element extension theory can combine qualitative and quantitative methods and overcome the difficulties of uncertainty and multiple attributes between transport system and economic system.

In conclusion, economic adaptation grade evaluation based on Matter-Element Extension with ANP can avoid the limitation of single method. After evaluating the economic adaptation level of the integrated transport system in Yunnan province, the results are satisfactory. But the index system constructed in this paper is not perfect, and further quantitative study is needed to obtain a more effective judge matrix. At the same time, the universality of the system needs further discussion, and whether there is a better comprehensive weight calculation method remains to be studied.

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