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Evaluation System and Service Innovation of Railway Transportation based on Factor Analysis

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Abstract

With the continuous reform and development of modern railway freight transport industry, especially under the rapid development of high-speed railway and railway freight reform. The freight transportation system not only ensures the safety, but also promotes the improvement of efficiency, and has achieved a large number of management and technological innovation achievements. It has laid a foundation for the smooth implementation of the strategy of high speed and heavy load and the safe development of freight transportation. With the continuous progress of railway freight transport management, in recent years, there have been many freight transport safety accidents and transport organization disputes. Therefore, it is necessary to continuously improve the railway freight transport safety management technology. How to evaluate and select the right shipping enterprise can help the railway department to carry out the daily transportation organization and customer management.

Keywords

Factor analysis; Railway freight transportation; Shipper; Evaluation system.

1. INTRODUCTION

The rapid development of China's national economy has led to a rapid increase in the demand for goods transportation in the whole society. Moreover, with the rapid development of high-tech industry, the structure of transportation products will be gradually lightened. The demand for freight transport is obviously manifested in the diversification of service levels and the improvement of service quality standards. This not only requires the transportation department to improve the service quality to meet the needs of customers, but also requires the railway department to select the most suitable customers when choosing the consigning enterprises.

Railway transportation is one of the most important modes of transportation in China, and railway transportation has always been in the leading position in the freight transportation market. However, the railway freight transportation has the disadvantages of low freight demand satisfaction rate, low timeliness of freight transportation, opaque organization process of freight transportation, and unable to track goods in real time. Railway freight transport has been unable to meet the service needs of customers. In order to gain the competitive market share, the railway freight department should evaluate and compare the best shippers according to the actual capacity of railway transportation and scientific theory. Through factor analysis, this paper finds out the main factors that affect the efficiency and service quality of the existing railway freight transport process. Through the quantitative calculation of the main factors, an effective evaluation model is formed by using information technology.

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At present, the relevant literature is limited, most of the literature focuses on the shipper's choice and optimization of transportation mode or transportation enterprise. Bharadwaj used empirical research method to get the evaluation index of supplier selection in the process of electronic parts procurement [1]. Based on Dickson's index, Weber and Zhang sorted the number of references cited by various indicators from 1966 to 2000, and summarized the change trend of enterprise's supplier evaluation standards [2]. Tae Seung Kim et al. Made a further theoretical study on the evaluation index of carrier, and found that service index gradually becomes more important than cost index in carrier selection. On this basis, an empirical analysis of the carrier's evaluation index [3]. Compared with the evaluation indexes of other suppliers, Wei Zhong et al. Concluded that the evaluation indexes of logistics suppliers are more focused on Service [4-6]. Tong Ming-rong made a theoretical analysis of carrier evaluation indicators from three aspects of functionality, customers and stability [7]. On the basis of previous studies, Liu Jian improved the index system of carriers from five aspects: service cost, operation efficiency, quality effect, technical level and personnel quality [8].

2. FACTOR ANALYSIS

2.1. Basic Principles of Factor Analysis

Factor analysis is a method to simplify the analysis of the variable combinations that affect each other. By analyzing the relationship between the variables, a large number of original data can be divided into a number of unrelated factors that can contain all indicators, and then a linear combination can be obtained [9].

Formula (1) is the standard mathematical model of factor analysis, where $Z_1, Z_2 \cdots Z_m$ is the original variable and $F_1, F_2 \cdots F_P$ is the common factor [10]. It can be expressed in the form of matrix as follows:

$$Z_j = \sum_{i=1}^{p} a_{ij} F_i + c_i U_i, \quad j = 1, 2, \cdots, m \tag{1}$$

In formula (1), there are matrices C and U that can be defined as:

$$C = \begin{bmatrix} c_1 & & \\ & \ddots & \\ & & c_m \end{bmatrix} \tag{2}$$

$$U = \left(U_1, U_2, \cdots, U_m\right)^T \tag{3}$$

Among them, the assumption of factor analysis is [11]:

(1) The common factor F is not related to the variable U, that is, a = 0;

(2) The common factors are linearly independent, the mean value is 0, the variance is 1.

Factor analysis needs to normalize the data and analyze the correlation between the data. And according to the analysis results, the factor matrix is established, and the eigenvalue of the incidence matrix is obtained by solving, and finally the eigenvector is obtained. Through SPSS, the scores of factors can be quantified in detail, and the weight and contribution rate of each factor can be determined. The formula of factor score is as follows:

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$$Q = \sum_{k=1} \varpi_k Q_k \tag{4}$$

Where, ϖ_k ——factor weight of k;

Q ——factor score of k;

F ——the number of factors.

2.2. Steps of Factor Analysis

Factor analysis needs to be carried out through SPSS, and the specific steps are as follows:

(1) Data acquisition

Collect relevant data, determine the variables to be used in factor analysis, and sort out the relevant data;

(2) Adaptability test

After collecting the data, the applicability of the data is tested to analyze whether the data can be analyzed by factor analysis. It is generally determined by KMO statistics and Bartlett's spherical test. If the value of KMO is between 0.5 and 1, factor analysis can be carried out; if Bartlett's spherical test value is small, then the matrix is identity matrix;

(3) Extraction factor

There are three methods to extract factors. First, eigenvalue extraction. If the eigenvalue is greater than 1, it is the main factor. Secondly, the cumulative contribution rate is extracted, and the factors whose cumulative contribution rate is greater than 85% are extracted. Third, the extraction of scree plot. According to the order of selecting factors, the scatter graph of characteristic roots is obtained. The number of common factors is the number of characteristic roots before the inflection point;

(4) Factor naming

After determining the factors, the factors are named according to their different meanings, so as to express the relationship between the factor variables and the original variables more scientifically;

(5) Factor score was calculated

The eigenvalue, eigenvector and cumulative variance contribution rate were calculated. The calculation formula is as follows:

$$X_{ij} = \frac{X_{ij} - \overline{X_j}}{\sqrt{S_j}}, i = 1, 2, \cdots, p; j = 1, 2, \cdots, m \tag{5}$$

$$\overline{X_j} = \frac{1}{m} \sum_{j=1}^{m} X_{ij} \tag{6}$$

$$S_j = \frac{1}{m-1} \sum_{j=1}^{m} \left(X_{ij} - \overline{X_j} \right), i = 1, 2, \cdots, p \tag{7}$$

After the normalized matrix is obtained, the related coefficient matrix, eigenvalue and common factor are calculated. The formula for calculating the cumulative variance of common factor is as follows:

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$$a_k = \sum_{i=1}^{k} S_i^2 \Big/ P = \sum_{i=1}^{k} \lambda_i \Big/ \sum_{i=1}^{p} \lambda_i \tag{8}$$

The initial factor load matrix is rotated to analyze practical problems more scientifically. After rotation, the load matrix can explain each common factor more clearly. Finally, the factor score and comprehensive score are estimated, and the calculation formula is as follows:

$$F_m = \overline{W_{11}} X_{11} + \overline{W_{12}} X_{21} + \cdots + \overline{W_{1p}} X_{p1} \tag{9}$$

$$F_i = \overline{W_{i1}} X_1 + \overline{W_{i2}} X_2 + \cdots + \overline{W_{ip}} X_p \tag{10}$$

3. EXAMPLE VERIFICATION

After selecting the index of factor analysis. In this paper, seven shippers are taken as the research object, and the factor analysis of the data obtained by SPSS can finally get the actual ranking of the comprehensive competitiveness of each company.

3.1. Sample Selection and Data Sources

This paper selects seven consigning enterprises which have cooperation with Wuxi Business Department of Shanghai freight center of Shanghai Railway Administration as the objects of SPSS analysis, which are recorded as a, B, C, D, e, F, G.

3.2. Factor Analysis Index System

The selection of indicators has a great impact on the results of factor analysis. In order to make the data more objective and real, we need to consider many factors. After comprehensive consideration, this paper selects the following indicators:

(1) Profitability. Operating capacity includes two parts: return on net assets and net profit, which refers to the ability of enterprises to obtain profits or capital appreciation through certain means.

(2) Business capacity. Business capacity includes three aspects: the turnover rate of accounts receivable, the turnover rate of inventory and the turnover rate of current assets. Generally speaking, the operating capacity refers to the ability of capital turnover between the shipping enterprise and the carrier enterprise. Only with good operation ability can the freight collection of the carrier enterprise be guaranteed.

(3) The value of the goods. Freight capacity includes four aspects: transportation time value, transportation time adaptability, transportation cost and transportation demand capacity. The freight transportation capacity refers to the dependence of the shipping enterprise on the railway transportation. With the help of these indicators, we can make a reasonable judgment on the development prospect of the shipping enterprise, so as to make the next decision.

(4) Solvency. Solvency includes quick ratio and cash ratio. Debt repayment is the judgment of the development of the shipping enterprise, which directly affects the long-term development of the enterprise.

(5) Management ability. The management ability includes the per capita management fee of the enterprise.

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Table 1. Evaluation index of factor analysis method

First-class	Second-class	Symbol	First-class	Second-class	Symbol
Profitability	Return on assets	X1	Freight value	Time adaptability	X7
	Net profit	X2		Transportation expenses	X8
Operating capacity	Fund turnover rate	X3		Transport demand	X9
	Inventory turnover	X4	Solvency	Quick ratio	X10
	Turnover rate	X5		Cash ratio	X11
Freight value	Time value	X6	Management ability	Per capita management fee	X12

3.3. Research Model and Case Analysis

This paper uses the data collected by SPSS for comprehensive analysis to obtain the factor ranking and comprehensive ranking of each enterprise. On this basis, the dynamic analysis of the results obtained [12].

The initial data were input into SPSS, and the significant level was 0.5. KMO and $Bartlett$ tests are carried out, the results are shown in Table 2.

Table 2. Data test before factor analysis

Select enough KMO metric	0.723
Approximate chi square	572.69
df	97
sig	0.00

According to the test data in the table, the measurement value of KMO is 0.723 > 0.5. The approximate chi square is 572.69, and the probability of significance decreases. Each index meets the requirements of factor analysis, which can be used for factor analysis of data.

Factor analysis process. Firstly, it is necessary to determine the eigenvalue, eigenvector and variance contribution rate of the matrix to determine the common factor in the matrix equation [13]. The eigenvalues and cumulative variance contribution rate of the matrix equation are calculated by SPSS, as shown in Table 3.

Table 3. Total variance required for factor analysis

Explain the total variance (%)									
Initial eigenvalue				Extract sum of squares load			Rotate sum of squares load		
	total	varia-nce	accum-ulate	total	varian-ce	accumulate	total	variance	accum-ulate
1	3.79	31.88	31.88	3.79	31.88	31.88	3.01	25.68	25.68
2	2.93	24.07	55.94	2.93	24.07	55.94	2.54	21.66	47.34
3	2.17	18.96	74.91	2.17	18.96	74.91	2.43	18.65	65.98
4	1.25	9.70	84.61	1.25	9.70	84.61	2.06	18.63	84.61
5	0.78	6.20	90.81						
6	0.46	3.48	94.30						
7	0.26	2.08	96.38						
8	0.18	1.55	97.93						
9	0.13	1.21	99.14						
10	0.04	0.54	99.67						
11	0.03	0.25	99.92						
12	0.01	0.08	100.00						

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The scree plot generated by SPSS is shown in Figure 1. It can be seen that the eigenvalues of the first four factors decreased rapidly. At the eighth factor, the decline slowed down obviously and the curve skew rate became smooth, which indicated that the contribution rate of cumulative variance of the remaining factors was relatively small.

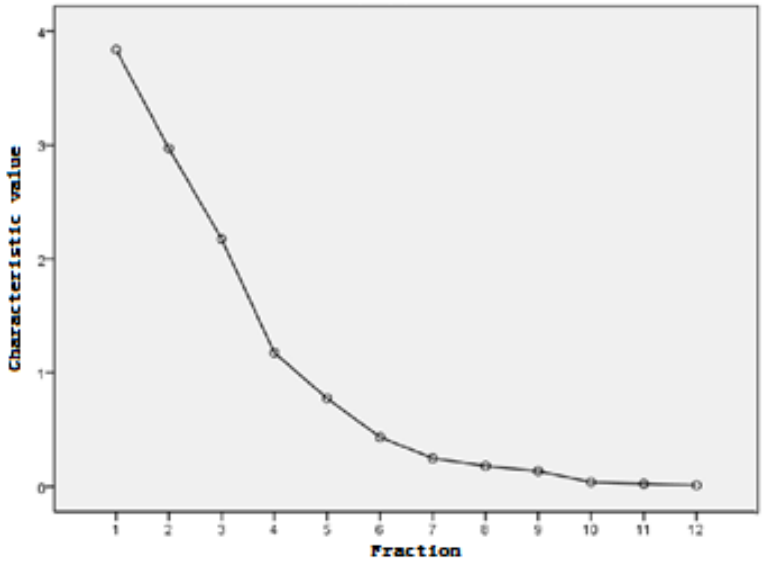

Fig 1. Scree plot

By calculating the factor load matrix in the initial state, after orthogonal rotation, the common factor score coefficient matrix is obtained, as shown in Table 4.

Table 4. Common factor score coefficient matrix

Name	Component			
	1	2	3	4
X1	-0.061	0.396	-0.070	-0.039
X2	-0.035	0.358	0.005	-0.049
X3	0.137	0.330	-0.068	-0.038
X4	0.208	0.096	-0.092	0.033
X5	0.382	0.009	-0.074	-0.181
X6	-0.252	0.020	-0.022	-0.044
X7	0.021	0.030	0.334	-0.021
X8	-0.144	-0.080	0.071	0.572
X9	-0.064	-0.095	0.407	0.133
X10	0.326	-0.080	0.045	-0.112
X11	0.043	0.067	-0.367	-0.015
X12	-0.062	-0.033	0.026	0.500

This paper analyzes 7 shipping enterprises and calculates the scores of 5 public factors. The calculation process is as follows.

$$F_{ij} = a_{ij} b_j \tag{11}$$

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$$F = \sum F_{ij} = \sum_{j=1}^{12} a_{ij} b_j \tag{12}$$

The five common factors of formula 11-12 are completely unrelated after rotation, so they are completely independent, which proves that the common factor selected is scientific and effective.

The five common factors of formula 11-12 are completely unrelated after rotation, so they are completely independent, which proves that the common factor selected is scientific and effective.

The first factor accounts for 25.04% of the competitiveness of shipping enterprises, and the value of F_1 has a large load (> 0.5) in $X_2(0.653)$, $X_9(0.921)$, $X_{10}(-0.805)$, $X_{11}(0.867)$, so F_1 is defined as profit and repayment factor. The second factor F_2 is the operating income factor, which contributes 22.22% to the competitiveness of shipping enterprises. At the same time, the value of F_2 has a large load (> 0.7) in $X_1(0.953)$, $X_3(0.943)$, $X_4(0.821)$. The third factor F_3 can be defined as time and management factor, and the contribution rate of this factor is 20.17%. Here, the value of F_3 has a large load (> 0.7) in $X_5(0.863)$, $X_6(0.908)$, $X_{12}(-0.844)$. The fourth factor F_4 is defined as the freight demand factor, and the contribution rate of this factor is 17.20%. the value of F_4 has a large load (> 0.7) in $X_7(0.953)$, $X_8(0.930)$.

Through the above formula, the ranking of each public factor of 7 shipping enterprises can be obtained through calculation, as shown in Table 5.

Table 5. Common factor score and ranking of shipping enterprises

Enterp-rise	F_1	Rank-ing	F_2	Rank-ing	F_3	Rank-ing	F_4	Rank-ing
A	0.0477	3	-0.7310	6	1.6419	2	0.6303	1
B	0.9413	1	-0.7903	7	2.3916	1	0.6100	2
C	-0.0244	4	-0.4483	4	0.0474	7	0.4745	4
D	-0.8405	7	0.9340	2	0.1241	6	0.3967	5
E	-0.2150	6	0.5823	3	0.5076	5	0.2397	6
F	-0.1814	5	4.0034	1	1.0538	3	0.1061	7
G	0.3956	2	-0.7156	5	0.6044	4	0.5601	3

The comprehensive competitiveness of 7 shipping enterprises is obtained, as shown in Table 6.

Table 6. Comprehensive score and ranking of shipping enterprises

Enterprise	Score	Ranking	Enterprise	Score	Ranking
F	103.26	1	G	15.71	5
B	60.40	2	D	9.23	6
A	29.43	3	C	-1.45	7
E	22.52	4			

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4. CONCLUSION

According to the factor analysis, the score ranking of shipping enterprises and the effect of scree plot, the factors that have the greatest impact on the evaluation of shipping enterprises are profit and repayment factor, operating income factor, time and management factor, and freight demand factor. Profit and repayment factor and operating income factor accumulated as high as 55%. According to the data obtained in this paper, among the seven shipping enterprises, the transportation demand capacity of enterprise F ranks the first, and the profit and repayment factor, operating income factor, time and management factor all rank in the top five, and the competitiveness of enterprise F is 103.26. enterprise C ranked the bottom with -1.45. The difference between the two ends is very large, and the gap between the middle is relatively small. Generally speaking, factor analysis method has obvious effect in solving problems with many influencing factors and complicated situations.

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