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Research on Development of China's Logistics Industry

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***Abstract*—In recent years, China's economic level, the scale of infrastructure construction, and the degree of opening to the outside world have continuously increased, and logistics industry has been rapidly developed. Based on the provincial panel data from 2009 to 2017, this paper calculates the comprehensive score of logistics development level by means of entropy weight method and Catastrophe Progression Method. The results show that the comprehensive score of logistics development level in Guangdong Province ranks first. The logistics development level in Jiangsu, Shandong, Zhejiang, Hebei, Liaoning, Hubei and other provinces is also at a high level. The development level of the logistics industry in Qinghai, Gansu, Hainan, Ningxia, Tibet and other regions is relatively low. In general, China's logistics industry has shown a development trend of "Strong East, weak West".**

Keywords—logistics; entropy method; Catastrophe progression method

I. INTRODUCTION

In information age, the steady growth of the economy is inseparable from the development of the logistics industry. At the same time, the logistics industry, as a basic and strategic industry, plays an important supporting role in the development of the national economy. With the deepening of globalization, the whole society has paid more and more attention to the development of logistics industry in the new era. The process of new industrialization, informationization, urbanization and agricultural modernization has continued to advance. The pace of industrial restructuring has accelerated. The consumption level and individualization of residents demand is also constantly improving. It is urgent to analyze the level of logistics development and explore the driving factors that affect the development of logistics to meet the needs of social and economic development. The accumulation of logistics industry helps to ensure the professionalization of the industry and enhance China's comprehensive competitiveness. In the "13th Five-Year Plan" of 2016, China clearly put forward that it is necessary to intensify efforts to develop the modern logistics industry, and has repeatedly mentioned logistics, express, internet, railway, highway, and aviation related to logistics.

In recent years, scholars have made some achievements in the research of logistics development level.

Lalita A. (2001) selected demographic and economic indicators to analyze the overall market potential and economic strength of the country. Then several factors related to distribution and promotion of goods in these countries are examined in detail. Finally, the two sets of classification schemes above are combined to develop a two-dimensional country-cluster matrix [1].

Frank P.van den Heuvel (2013) analyzes location dynamics of logistics establishments in relation to spatial clustering.Then longitudinal empirical data on logistics establishments in a Dutch province are used. Six general conclusions are drawn on spatial concentration and location decisions of logistics firms [2].

Yu Yubing (2008) expounds the present situation of city logistics in Anhui Province, selecting index system of logistics development to evaluate the city logistics development level and discuss the fundamental pattern of city logistics development level, then points out the existing problem and gives suggestion to develop the city logistics in Anhui province [3].

Jin Fenghua (2010) proposed properties of regional logistics field based on field theory and logistics field theory. Built up an evaluation index system, analyzed each regional logistics development level, and then proposed several suggestions for developing regional logistics [4].

Zhao Guang (2015) proposed the logistics system evaluation based on catastrophe theory. After decomposing the appraised goal with many layers, this method combines the catastrophe theory and the membership function of fuzzy mathematics to get the catastrophe progression of various levels indexes from the lower indexes to the upper indexes and obtains the catastrophe progression of the logistics system. And then, the logistics system is evaluated by sorting the catastrophe progression [5].

Tang Jianrong (2019) utilizes TOPSIS model to measure the development level of provincial logistics industry, and combines Kernel density estimation method and ESDA method to analyze the law of industrial evolution. The results prove that spatial difference and spatial autocorrelation exist in the development of China's provincial logistics industry [6].

II. RESEARCH METHODS

A. Entropy Weight Method

The entropy weight method determines the objective weight according to the degree of change of the indicator data. Generally, if the information entropy of an indicator is smaller, it indicates that the degree of change of the indicator data is larger. That is, the more information is provided, the more the role can be played in calculating the comprehensive evaluation index, that is, the more the weight is Big. On the contrary, the larger the information entropy of an indicator, the smaller the degree of change of the indicator data, that is, the smaller the amount of information provided, the smaller the effect that can be played in calculating the comprehensive evaluation index, that is, the smaller its weight.

The steps of the Entropy Weight Method are as follows:

1. Standardization of the data of each index.

Assuming that kindices are given, $X_1, X_2, \dots \dots X_k$.

Where, $X_i = \{x_1, x_2, \dots \dots x_n\}$.

Assume that the normalized values for each indicator data are $Y_1, Y_2, \dots \dots Y_k$, then,

$$Y_{ij} = \frac{x_{ij} - \min(x_i)}{\max(x_i) - \min(x_i)} \tag{1}$$

2. Solving Information Entropy of Indicators

According to the definition of information entropy in information theory, information entropy of a group of data:

$$E_j = -ln(n)^{-1} \sum_{i=1}^{n} p_{ij} lnp_{ij} \tag{2}$$

Where,

$$p_{ij} = Y_{ij} / \sum_{i=1}^{n} Y_{ij} \tag{3}$$

If p_{ij}=0, then,

$$\lim_{p_{ij} \to 0} p_{ij} lnp_{ij} = 0 \tag{4}$$

3. Determining the Weight of Indicators

Calculate the information entropy of each index, and then calculate the weight of each index.

$$W_i = \frac{1 - E_i}{k - \sum E_i} (i = 1,2, \dots \dots, k) \tag{5}$$

B. Catastrophe Progression Method

The catastrophe progression method firstly decomposes the evaluation objectives to construct a hierarchical index. Then the catastrophe fuzzy membership function is generated by combining catastrophe theory with fuzzy mathematics. Then uses the normalization formula to obtain the total membership function. Finally, evaluation objectives are ranked and analyzed.

The basic steps are:

1.According to the evaluation target object, the multi-level decomposition of the total index is carried out to form the target hierarchy of the inverted tree diagram. It is only necessary to know the specific data corresponding to the lowest sub-indicator. Generally, the control variables of catastrophe coefficients can not exceed four, that is, the sub-indicators after the decomposition at each level should not exceed 4.

2.According to the constructed index system, the catastrophe system type is determined. There are seven types of mutation system, the most common of which are folding mutation system, cusp mutation system, swallow tail mutation system and butterfly mutation system.

Folding mutation system:

$$f(x) = x^3 + ax \tag{6}$$

Cusp mutation system:

$$f(x) = x^4 + ax^2 + bx \tag{7}$$

Swallow tail mutation system:

$$f(x) = \frac{1}{5}x^5 + \frac{1}{3}ax^3 + \frac{1}{2}bx^2 + cx \tag{8}$$

Butterfly mutation system

$$f(x) = \frac{1}{6}x^6 + \frac{1}{4}ax^4 + \frac{1}{3}bx^3 + \frac{1}{2}cx^2 + dx \tag{9}$$

f(x) represents the potential function of the state variable x of the constructed index system. a, b, c, d represents control variables. If there is only one sub-indicator in an indicator, the system can be regarded as a folding mutation system. If one indicator includes two sub-indicators, and the system can be regarded as a cusp mutation system. If one indicator includes three sub-indicators, the system can be regarded as a swallow tail mutation System. If an indicator includes four sub-indicators, the system can be considered as a butterfly mutation system.

3. Export normalization formula.

The four normalized formulas for the control variables of the mutated mathematical model are:

$$x_a = |a| \tag{10}$$

$$x_a = |a|^{\frac{1}{2}}, x_b = |b|^{\frac{1}{3}} \tag{11}$$

$$x_a = |a|^{\frac{1}{2}}, x_b = |b|^{\frac{1}{3}}, x_c = |c|^{\frac{1}{4}} \tag{12}$$

$$x_a = |a|^{\frac{1}{2}}, x_b = |b|^{\frac{1}{3}}, x_c = |c|^{\frac{1}{4}}, x_d = |d|^{\frac{1}{5}} \tag{13}$$

4. Use the normalization formula for comprehensive evaluation.

III. Calculate Index Weight of Logistics Development Level

A. Constructing Index System of Logistics Development Level

Firstly, the index system of each level of logistics development is determined, as shown in Table I.

TABLE I. INDEX SYSTEM

First level index	***Second level index***	***Third level index***
Comprehensive Development Level of Logistics	Industrial scale (X_1)	Freight Ton-Kilometers (a_1)
		Value-added of transport, storage and post (b_1)
	Economic development (X_2)	Tertiary industry (a_2)
		Per capita GDP (b_2)
		Per capita total retail sales of consumer goods (c_2)
	Logistics condition (X_3)	Number of employed person in urban units of transport, storage and post (a_3)
		Average wage of employed persons in transport, storage and post (b_3)

First level index	Second level index	Third level index
		Total investment in fixed assets in transport, storage and post (c_3)
	Infrastructures Construction (X_4)	Railway density (a_4)
		Highway density (b_4)
		Possession of trucks for highway business transportation (c_4)
		Internet subscribers (d_4)

The second level index, the industrial scale is a cusp mutation system, the control variable is the Freight Ton-Kilometers (100 million tons), value-added of transport, storage and post (100 million yuan), marked as a_1, b_1, complementary. Economic development is the swallow tail mutation system, the control variables are the tertiary industry value (100 million yuan), the per capita GDP (yuan), and per capita total retail sales of consumer goods (yuan/person), marked as a_2, b_2, c_2, complementary. Logistics condition is the swallow tail mutation system, the control variables are number of employed person in urban units of transport, storage and post (10,000), average wage of employed persons in transport, storage and post (yuan), total investment in fixed assets in transport, storage and post (100 million yuan)), marked as a_3, b_3, c_3, complementary. Infrastructures construction is a butterfly mutation system, the control variable is railway density (km/km^2), highway density (km/km^2), possession of trucks for highway business transportation (10,000 vehicles) and internet subscribers (10,000 people), marked as a_4, b_4, c_4, d_4, respectively.

The first level index, comprehensive development level of logistics is a butterfly-type mutation system, the control variable is industrial scale, economic development, logistics condition, infrastructures construction, marked as X_1, X_2, X_3, X_4.

B. Calculation of Index Weight

According to the China Statistical Yearbook, the indicator data is input into the excel table (here weight is taken as an example in 2009), and the relative weights of each indicator are calculated by using Matlab software, as shown in Table II.

TABLE II. INDEX WEIGHT

Second level index	Weight	Third level index	Weight
X_1	0.19410	a_1	0.11266
		b_1	0.08144
X_2	0.29986	a_2	0.10049
		b_2	0.09927
		c_2	0.10010
X_3	0.19447	a_3	0.05922
		b_3	0.07137
		c_3	0.06388
X_4	0.31157	a_4	0.08874
		b_4	0.06445
		c_4	0.07432
		d_4	0.08406

IV. CALCULATING LOGISTICS DEVELOPMENT LEVEL

After applying the Matlab, standardizing all the indicators, the Excel formula is used to calculate the logistics development level of each province and city from 2009 to 2017. Taking the standardized data of Shanghai's indicators in 2009 as an example, the process of calculating the level of logistics development by the catastrophe progression method is introduced.

1. Third level index.

a_1, b_1, cusp mutation system, $a_1 > b_1$;

$x_{a1} = a_1^{\frac{1}{2}} = 1$;

$x_{b1} = b_1^{\frac{1}{2}} = 0.7091$;

So, $X_1 = \frac{x_{a1}+x_{b1}}{2} = 0.8546$;

a_2, b_2, c_3, swallow tail mutation system, $a_2 > c_2 > b_2$;

$x_{a2} = a_2^{\frac{1}{2}} = 0.6985$;

$x_{c2} = c_2^{\frac{1}{3}} = 0.9262$;

$x_{b2} = b_2^{\frac{1}{4}} = 1$;

So, $X_2 = \frac{x_{a2}+x_{b2}+x_{c2}}{3} = 0.8749$;

a_3, b_3, c_3, swallow tail mutation system,

$b_3 > c_3 > a_3$;

$x_{b3} = b_3^{\frac{1}{2}} = 1$;

$x_{c3} = c_3^{\frac{1}{3}} = 0.8086$;

$x_{a3} = a_3^{\frac{1}{4}} = 0.9016$;

So, $X_3 = \frac{x_{a3}+x_{b3}+x_{c3}}{3} = 0.9034$;

a_4, b_4, c_4, d_4, butterfly mutation system, $a_4 > d_4 > c_4 > b_4$;

$x_{a4} = a_4^{\frac{1}{2}} = 0.8154$;

$x_{d4} = d_4^{\frac{1}{3}} = 0.6150$;

$x_{c4} = c_4^{\frac{1}{4}} = 0.6599$;

$x_{b4} = b_4^{\frac{1}{5}} = 1$;

So, $X_4 = \frac{x_{a4}+x_{b4}+x_{c4}+x_{d4}}{4} = 0.7726$;

2. Second level index

X1, X2, X3, X4, butterfly mutation system,

$X_4 > X_2 > X_3 > X_1$;

So, $L_4 = X_4^{\frac{1}{2}} = 0.8790$;

$L_2 = X_2^{\frac{1}{3}} = 0.9564$;

$L_3 = X_3^{\frac{1}{4}} = 0.9749$;

$L_1 = X_1^{\frac{1}{5}} = 0.9691$;

3. First level index

$L = \frac{L_1+L_2+L_3+L_4}{4} = 0.9448;$

That is, the logistics development level of Shanghai in 2009 was 0.9448.

In the same way, the comprehensive scores of the development level of the logistics industry in 31 provinces and cities of China (excluding Taiwan, Hong Kong and Macao Taiwan) from 2009 to 2017 are shown in Table III.

TABLE III. INDEX SYSTEM

Provinces, Autonomous Regions	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Heilongjiang	0.8399	0.8397	0.8359	0.8341	0.8367	0.8343	0.8328	0.8293	0.8211
Inner Mongolia	0.8549	0.8571	0.8588	0.8607	0.8645	0.8579	0.8497	0.8456	0.8633
Jilin	0.8305	0.8300	0.8316	0.8354	0.8364	0.8353	0.8338	0.8304	0.8287
Xinjiang	0.7933	0.7928	0.7931	0.7983	0.8028	0.8044	0.7962	0.7827	0.8323
Beijing	0.9185	0.9159	0.9123	0.9155	0.9095	0.9093	0.8937	0.8896	0.8524
Shanxi	0.8609	0.8632	0.8616	0.8607	0.8605	0.8548	0.8521	0.8449	0.8265
Shandong	0.9399	0.9417	0.9422	0.9372	0.9400	0.9345	0.9413	0.9393	0.9063
Hebei	0.9013	0.9031	0.9015	0.9028	0.9128	0.9044	0.9141	0.9082	0.8771
Henan	0.8893	0.8887	0.8848	0.8864	0.8833	0.8848	0.8901	0.8858	0.8436
Gansu	0.7714	0.7628	0.7653	0.7654	0.7762	0.7715	0.7664	0.7631	0.7686
Ningxia	0.7527	0.7548	0.7534	0.7525	0.7588	0.7510	0.7462	0.7412	0.7439
Qinghai	0.7178	0.7186	0.7182	0.7206	0.7179	0.7193	0.7091	0.7046	0.7739
Shaanxi	0.8460	0.8496	0.8493	0.8474	0.8537	0.8541	0.8555	0.8525	0.8397
Jiangsu	0.9260	0.9298	0.9327	0.9302	0.9434	0.9403	0.9426	0.9385	0.9156
Anhui	0.8404	0.8416	0.8435	0.8486	0.8690	0.8616	0.8713	0.8715	0.8530
Tibet	0.3390	0.3338	0.3557	0.3392	0.3320	0.3007	0.3617	0.3647	0.4995
Hubei	0.8673	0.8749	0.8749	0.8808	0.8861	0.8829	0.8882	0.8872	0.8658
Zhejiang	0.9226	0.9227	0.9223	0.9206	0.9221	0.9199	0.9222	0.9165	0.8897
Sichuan	0.8554	0.8576	0.8580	0.8620	0.8653	0.8646	0.8667	0.8684	0.8576
Guizhou	0.7329	0.7329	0.7337	0.7578	0.7650	0.7659	0.7843	0.7867	0.8119
Chongqing	0.8397	0.8422	0.8441	0.8489	0.8586	0.8545	0.8574	0.8575	0.8388
Jiangxi	0.8309	0.8342	0.8340	0.8339	0.8382	0.8367	0.8382	0.8359	0.8215
Hunan	0.8682	0.8689	0.8676	0.8669	0.8709	0.8667	0.8703	0.8689	0.8459
Yunnan	0.8014	0.8025	0.8030	0.8003	0.8075	0.8034	0.8059	0.8089	0.8164
Fujian	0.8790	0.8799	0.8784	0.8822	0.8865	0.8847	0.8899	0.8882	0.8640
Guangxi	0.8305	0.8337	0.8304	0.8281	0.8404	0.8367	0.8430	0.8414	0.8310
Guangdong	0.9517	0.9499	0.9488	0.9447	0.9519	0.9511	0.9553	0.9564	0.9262
Hainan	0.7706	0.7746	0.7670	0.7708	0.7698	0.7751	0.7735	0.7679	0.7587
Tianjin	0.9093	0.9069	0.9074	0.9102	0.9006	0.9010	0.8821	0.8760	0.8166
Liaoning	0.9056	0.9081	0.9062	0.9114	0.9213	0.9150	0.9155	0.8903	0.8661
Shanghai	0.9448	0.9460	0.9455	0.9422	0.9367	0.9391	0.9355	0.9317	0.8572

There are significant differences in the development level of China's logistics industry from 2009 to 2017. The development of logistics industry in Guangdong, Jiangsu, Shandong, Zhejiang, Hebei, Liaoning, Hubei is the highest; the development level of logistics industry in Qinghai, Gansu, Hainan, Ningxia and Tibet is lower. The logistics development levels in Zhejiang, Liaoning, Beijing, Shanghai, Tianjin have declined slightly. The growth rate of Xinjiang and Tibet is obvious. Overall, China's logistics industry shows a trend of “strong in the East and weak in the west”. There are significant differences in the initial level, development path and development speed in different provinces and autonomous regions.

V. CONCLUSION

The improvement of the level of economic development is the primary guarantee for the development of the logistics industry. The gap between the industrial developments in different regions is too large. Therefore, regional coordination should be strengthened. Supporting for weak areas of logistics industry development should be strengthened. Inter-regional industrial cooperation should be strengthened. The co-construction and sharing of transportation hub facilities should be improved. The interconnection between branch lines and main lines should be strengthened. The linking lines of transportation modes should be optimized. Narrow the gap of the regional economy and establish an interregional economic linkage mechanism, so as to promote complementary advantages of regional circulation resources. Build a new multi-dimensional and three-dimensional logistics network. Promote the sustainable and healthy development of the logistics industry.

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