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Article

Evaluation of Green Logistics Development in Fujian, China

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Abstract: Green logistics has become important in the development of China's logistics industry, and the evaluation and monitoring of the development of green logistics have attracted much research interest. Green logistics is closely related to the overall logistics development based on the awareness of sustainable development. Taking Fujian Province as an example, we construct the evaluation index system of logistics development to evaluate the results of green development. After standardizing and dimensioning the evaluation index data with SPSS, the score of logistics development level in Fujian from 2014 to 2019 is obtained by using principal component analysis, and the development of green logistics in the region is evaluated based on the proportion of energy consumption of logistics industry during this period. The results show that the development of green logistics in this region is in a good direction, and the logistics industry presents sustainable development.

Keywords: Green Logistics, Principal Component Analysis, Evaluation, Fujian

1. Introduction

As China's economy has gradually entered a high-quality stage, "energy conservation, emission reduction, and green development" has become the main consensus of the government and society. Sustainable development is a critical theory and strategy to promote the development of the regional economy [1]. Low carbon policy has gradually become a new trend, and the green industry has been focused on for the sustainable development of society. The logistics industry is the strategic foundation of national economic development and is required to undertake the important mission of energy conservation and carbon reduction [2]. In response to the UN's energy conservation and emission reduction targets, China is making efforts to accelerate the development of green logistics, integrate transportation resources, and improve utilization efficiency. Therefore, the development of green logistics has become the main focus of the effort. To understand the development of green logistics in Fujian Province in recent years, we calculate the comprehensive score of logistics development in this area and estimate the energy consumption of the logistics industry by using the principal component analysis. The result reveals the comparison of the relation between the logistics industry and its energy consumption, which helps to understand the development of green logistics in Fujian Province in recent years.

2. Green Logistics

Green logistics mainly refers to the development of green logistics discipline that is gradually formed and established by its interaction with the current economic environment, society, ecology, and logistics environment [3]. Green logistics theory is mainly based on the following four foundations.

(1) Sustainable development

The goal of sustainable development is to protect resources and the ecological environment to meet various human needs, so as not to threaten the survival and needs of future generations [4]. Green logistics is a logistical activity that adheres to sustainable development to achieve long-term, sustainable and stable development. It uses environmentally symbiotic logistics management to change the one-way relationship between the original economic development, and logistics and consumption. While restraining the harm caused by logistics to the environment, a logistics system is formed to promote economic development and human health development and change to circular logistics [5].

(2) Ecological economics

The field of logistics involves economy and ecological environment as a bridge between economic benefits and ecological benefits [6]. Ecological economics is to coordinate the proportion of economic benefits and ecological-environmental benefits in logistics and build a development model of harmonious operation and mutually beneficial symbiosis between ecology and economy. It is an inevitable choice to deal with ecological and environmental problems at present.

(3) Ecological ethics

Ecological ethics is the moral requirement of the green logistics theory. It analyzes the relationship between man and nature from a moral perspective [7] and requires human beings to have a sense of morality and be responsible for nature when dealing with nature.

(4) Circular economy

The core idea of the circular economy is resource recycling [8], which is also the core support of green logistics. Therefore, the logistics industry needs to strive to realize the effective recovery and utilization of renewable resources, establish a complete logistics management system for the waste of raw materials in the logistics industry chain, improve the comprehensive utilization of resources, and reduce the waste from various resources in the logistics system. The purpose is to improve social and economic benefits and promote healthy and sustainable economic development.

In order to comply with the development trend of green and livable cities, production, living, and environment, we need to have green awareness [9]. Therefore, green logistics emphasizes the sustainable development of the logistics industry. The awareness of green logistics emphasizes paying attention to energy efficiency in the process of economic development to avoid the use of future generations' resources in advance. However, in the process of real economic growth, the logistics industry plays an auxiliary role in many industries. While the logistics industry makes an important contribution to modern economic development, it also produces negative effects such as environmental pollution and resource waste. Keeping the balance between contribution and environmental protection has become an urgent problem for governments and environmental institutions to solve. Therefore, the dilemma needs the awareness of green logistics to be solved.

3. Current Situation of Logistics in Fujian

From 2016 to 2020, Fujian Province has formed a large-scale integrated logistics development pattern of industry, network, and service. According to the data released by the Fujian Provincial Department of industry and information technology, in 2020, Fujian's GDP reached 4390.389 billion yuan with an increase of 3.3% from the previous year, which was 1% point higher than that of the world. The revenue of Fujian's logistics industry was 481.057 billion yuan, showing an increase of 2.3%. The added value of Fujian's logistics industry was 235.596 billion yuan with an increase of 5.0% from that of the last year at comparable prices. Among them, the added value of transportation, warehousing, and postal industry was 142.244 billion yuan with an increase of 4.8%. The business income of the wholesale and retail industry was 93.352 billion yuan with an increase of 5.3%. The added value of the logistics industry accounted for 5.4% of GDP, which was the same as that of the previous year. It accounted for 11.3% of the added value of the service industry with a decrease of 0.4%. According to preliminary statistics, the total amount of social logistics in the province in 2020 was 8757.346 billion yuan, having an increase of 3.1% at comparable prices, and the total demand for social logistics continued to expand. However, in 2020, the completed investment in the fixed assets of the Fujian logistics industry decreased by 13.2% of the last year's assets. Transportation, warehousing, and postal services decreased by 16.1%, while the wholesale and retail trade grew by 15.4%.

In response to the current national policy of integrating carbon peaking and neutralization into the overall economical and social development, the Fujian provincial government requires to accelerate the construction of a low-carbon transportation system and the development of green logistics, integrate transportation resources, and improve the utilization efficiency. Fujian Province is a leading area in ecological civilization. It has a good construction foundation to promote the green development of the industrial economy and realize green circular and low-carbon development. However, at present, the logistics industry is still in the stage of accelerated development, and there is a certain gap among developed provinces. For example, the utilization rate of logistics resources and the degree of logistics informatization still hinder the development of green logistics. At the same time, a large proportion of petrochemical energy must still be used because Fujian relatively is short of natural resources, especially in energy. According to China's energy statistical yearbook in 2018, Fujian's transportation, storage, and postal industry consumed 6.64 million tons of standard coal, and its energy consumption was 5.3626 million tons of standard coal, which is still higher than the use of the whole China. This indicates that Fujian needs to establish a modern green logistics system urgently.

4. Method and Results

Firstly, the principal component analysis method is used to evaluate the logistics development indicators in Fujian. The main steps are as follows.

(1) Standardize and execute index data are by SPSS

(2) Conduct factor analysis and dimensionality reduction

(3) Determine the correlation and significance of each index to determine whether it is suitable for principal component analysis
(4) Determine the number of principal components
(5) Calculate principal components (F_i)
(6) Name F_i
(7) Standardize F_i scores
(8) Calculate comprehensive component scores

4.1. Index Data Processing

Based on the understanding of the concept of logistics development and the basic principles of evaluation indicators, 12 comprehensive indicators such as economic environment, social environment, infrastructure, and energy consumption are selected from the Fujian statistical yearbook, the China energy statistical yearbook, and the China logistics yearbook. The evaluation index system of Fujian logistics development is established as shown in Table 1. This evaluation system shows the development of logistics scale in the region, including the development of green logistics. The collection of indicator data from 2014 to 2019 is shown in Table 2. Then, these data are standardized as shown in Table 3.

Table 1. Logistics development evaluation system in Fujian.

	Level 1 Indexes	Level 2 Indexes	Variables
Logistics development evaluation system in Fujian	Economic environment	Regional GDP (100 million yuan)	X_{11}
		Fixed asset investment in the logistics industry (100 million yuan)	X_{12}
		Added-value of logistics industry (100 million yuan)	X_{13}
	Social environment	Urbanization level (%)	X_{21}
		Number of employees in the logistics industry (10 thousand)	X_{22}
		Composition of college education (%)	X_{23}
	Infrastructure	Road area (million square meters)	X_{31}
		Freight volume (10000 tons)	X_{32}
		Cargo turnover (100 million ton-km)	X_{33}
	Energy consumption	Total amount of coal for transportation, storage, and postal industry (10000 tons)	X_{41}
		Total energy consumption of transportation, storage, and postal industry (10000 tons of standard coal)	X_{42}
		Gasoline consumption in transportation, storage,and postal industry (10000 tons)	X_{43}

Table 2. Index values from 2014 to 2019.

Variables \ Year	2014	2015	2016	2017	2018	2019
X_{11}	24942.07	26819.46	29609.43	33842.44	38687.77	42326.58
X_{12}	1979.50	2491.90	2678.10	2921.80	3035.70	3138.42
X_{13}	1320.35	1547.30	1685.18	1889.69	1984.35	1994.89
X_{21}	61.80	62.59	63.60	64.79	65.80	66.50
X_{22}	12.90	16.00	19.00	22.20	22.30	24.20
X_{23}	9.40	9.80	10.40	10.90	11.20	11.40
X_{31}	154.36	163.03	176.57	222.38	269.95	282.36
X_{32}	111779.00	111063.00	120379.00	132252.00	136974.00	133693.00

X_{33}	4783.48	5450.96	6074.83	6785.16	7652.89	8296.62
X_{41}	3.00	2.00	1.90	1.30	1.20	1.15
X_{42}	948.64	1004.55	1060.62	1204.37	1211.91	1389.93
X_{43}	167.40	190.95	215.11	230.00	237.87	251.87

Source: Fujian statistical yearbook, China energy statistical yearbook, China logistics yearbook.

Table 3. Standardized values of index from 2014 to 2019.

Year / Variables	2014	2015	2016	2017	2018	2019
ZX_{11}	-1.1343	-0.8600	-0.4523	0.1663	0.8743	1.4061
ZX_{12}	-1.7004	-0.5037	-0.0688	0.5003	0.7663	1.0063
ZX_{13}	-1.5456	-0.7036	-0.1921	0.5666	0.9178	0.9569
ZX_{21}	-1.2943	-0.8646	-0.3154	0.3317	0.8810	1.2616
ZX_{22}	-1.5128	-0.7950	-0.1003	0.6406	0.6638	1.1037
ZX_{23}	-1.4028	-0.9003	-0.1466	0.4816	0.8584	1.1097
ZX_{31}	-1.0289	-0.8726	-0.6285	0.1972	1.0546	1.2783
ZX_{32}	-1.0952	-1.1576	-0.3464	0.6875	1.0987	0.8130
ZX_{33}	-1.2946	-0.7933	-0.3248	0.2086	0.8603	1.3437
ZX_{41}	1.7518	0.3409	0.1999	-0.6466	-0.7877	-0.8582
ZX_{42}	-1.1530	-0.8101	-0.4663	0.4151	0.4614	1.5530
ZX_{43}	-1.5298	-0.7813	-0.0135	0.4598	0.7099	1.1549

4.2. Indexes Score Calculation and Naming

(1) Index of economical environment

Processing and analyzing economic environment indicators (ZX_{11}~ZX_{13}) with SPSS results in the KMO of sampling appropriateness of 0.673 (> 0.6) and the p is 0.00 (< 0.05), which is appropriate for principal component analysis. The variance contribution rate of the principal component is 96.431 (> 75%), which meets the requirements of the principal component. As the eigenvalue is 2.893 (> 1), the principal component can be extracted. The composition matrix is shown in Table 4.

Table 4. Composition matrix of economic environment indexes.

Indexes	Component matrix
Added-value of logistics industry (ZX_{13})	0.994
Fixed asset investment in the logistics industry (ZX_{12})	0.985
Regional GDP (ZX_{11})	0.967

According to the relevant knowledge of mathematical statistics, the relationship between the transformation matrix (U_i) of principal component analysis, the load factor matrix A_i and the eigenvalue λ is shown in Eq. (1). The F_i is calculated from Eq. (2). F_i is the final principal component score obtained by accumulating the product of each corresponding index weight (U_j) and index value (ZX_{ij}).

$$U_j = A_j / \sqrt{\lambda} \quad (1)$$

$$F_i = \sum_{j=1}^{n} ZX_{ij} \cdot U_j \quad (2)$$

ZX_{ij} : Standardized value of index of each year;

(U_j : weight of each index calculated according to principal component
A_j : component matrix
λ : eigenvalues of extracted components greater than 1)

Therefore, the F_1 score is calculated as $F_1=0.569ZX_{11}+0.579ZX_{12}+0.584ZX_{13}$. $F1$ is for the economic level of logistics.

(2) Index of social environment

The analysis result of social environment indicators (ZX_{21}–ZX_{23}) shows that the KMO of sampling appropriateness is 0.620, and the p is 0.00, which is appropriate for principal component analysis. The variance contribution rate of the principal component is 99.017%, which meets the requirements of the principal component. The eigenvalue is 2.971 so a principal component can be extracted. The composition matrix is shown in Table 5.

Table 5. Composition matrix of social environment indexes.

Indexes	Component matrix
Number of employees in logistics industry (ZX_{22})	.999
Urbanization level (ZX_{21})	.993
Composition of college education (ZX_{23})	.993

The score of F_2 is calculated according to Eqs. (1) and (2) as $F_2=0.576ZX_{21}+0.580ZX_{22}+0.576ZX_{23}$. F_2 is for the urbanization level of the logistics industry.

(3) Index of infrastructure

The analysis result of social environment indicators (ZX_{31}–ZX_{33}) shows that the KMO of sampling appropriateness is 0.752, and the p is 0.001. The variance contribution rate of the principal component is 96.504%, which meets the requirements of the principal component. The eigenvalue is 2.895. The composition matrix is shown in Table 6.

Table 6. Composition matrix of infrastructure indexes.

Indexes	Component matrix
Road area (ZX_{31})	.990
Cargo turnover (ZX_{33})	.986
Freight volume (ZX_{32})	.971

The score of F_3 is calculated according to Eqs. (1) and (2) as $F_3=0.582ZX_{31}+0.571ZX_{32}+0.579ZX_{33}$. F_3 is for the infrastructure level of logistics.

(4) Index of energy consumption

The analysis result of social environment indicators (ZX_{41}–ZX_{43}) shows that the KMO of sampling appropriateness is 0.640, and the p is 0.001. The variance contribution rate of the principal component is 94.974%, which meets the requirements of the principal component. The eigenvalue is 2.849. The composition matrix is shown in Table 7.

Table 7. Composition matrix of energy consumption indexes.

Indexes	Component matrix
Gasoline consumption in the transportation, storage, and postal industry (ZX_{43})	0.993
Total amount of coal for transportation, storage, and postal industry (ZX_{41})	-0.968
Total energy consumption of transportation, storage and postal industry (ZX_{42})	0.962

The score of F_4 is calculated as F_4=-0.573ZX_{41}+0.570ZX_{42}+0.588ZX_{43}. F_4 is for the energy consumption level of logistics.

Through the principal component analysis, the above 12 indicators are grouped into four component indicators reflecting logistics development in Fujian Province: the economic level of logistics (F_1), the urbanization level of logistics industry (F_2), the infrastructure level of logistics (F_3) and the energy consumption level of logistics (F_4). The four principal component indexes are used to evaluate the logistics development in Fujian Province. Although the energy consumption level of logistics (F_4) is the development indicator of the logistics industry, it is also the anti-indicator of green logistics. The higher the proportion of its comprehensive score in logistics development, the more unfavorable the development of green logistics in the development of the logistics industry.

4.3 Calculation of Principal Component Standard Score and Comprehensive Score

According to the standardized data (Table 3), the standardized evaluation index scores (F_i) of four logistics development principal components from 2014 to 2019 are calculated as shown in Table 8. The KMO of sampling appropriateness is 0.760, and the p is 0.005. The variance contribution rate of the principal component is 98.727%, which meets the requirements of the principal component. The eigenvalue is 3.949. The principal component matrix is shown in Table 9.

Table 8. Standard scores of logistics development evaluation index.

F_i \ Year	2014	2015	2016	2017	2018	2019
F_1	-2.533	-1.192	-0.409	0.715	1.477	1.942
F_2	-2.431	-1.478	-0.324	0.840	1.387	2.006
F_3	-1.974	-1.628	-0.752	0.628	1.739	1.986
F_4	-2.560	-1.117	-0.388	0.877	1.132	2.056

Table 9. Component matrix of logistics development evaluation index score.

Evaluation index	Component matrix
Urbanization level of logistics industry (F_2)	0.999
Economic level of logistics (F_1)	0.998
Energy consumption level of logistics (F_4)	0.993
Infrastructure level of logistics (F_3)	0.985

The weights of the evaluation index (F_i) are calculated with Eq. (2), and the weights are normalized as shown in Table 10. Therefore, the standard comprehensive score (D) is calculated as D=0.2511F_1+0.2513F_2+0.2478F_3+0.2498F_4.

Then, the comprehensive scores of logistics evaluation standards of Fujian Province from 2014 to 2019 are calculated as shown in Table 11. The score proportion of energy consumption is also calculated.

Table 10. Weights of evaluation index.

Evaluation index	Weights	Normalized weights
Economic level of logistics (F_1)	0.5022	0.2511
Urbanization level of logistics industry (F_2)	0.5027	0.2513

Infrastructure level of logistics (F_3)	0.4957	0.2478
Energy consumption level of logistics (F_4)	0.4997	0.2498

Table 11. Comprehensive score of logistics evaluation in 2014-2019.

Year	Comprehensive score	Proportion of energy consumption
2014	-2.3755	0.2693
2015	-1.3530	0.2062
2016	-0.4675	0.2074
2017	0.7655	0.2863
2018	1.4331	0.1973
2019	1.9974	0.2571

5. Discussion

The comprehensive development score of Fujian logistics continued to increase from 2014 to 2019, with a comprehensive evaluation score of -2.3755 and an overall score of 1.9974 in 2019. 2017 was a year of substantial expansion of Fujian's logistics industry. The four principal component scores increased significantly. In 2017, the proportion of logistics energy consumption also increased by 0.2863, but then the proportion of logistics energy consumption decreased. The proportion of logistics energy consumption showed an improvement in the development of green logistics and no deterioration. The proportion of logistics energy consumption decreased from 0.2693 to 0.1973 and then increased to 0.2571. The energy consumption of the logistics industry during this period is shown in Fig. 1. Although the total energy consumption of logistics increases year by year, the coal energy consumption decreases. In addition, although the annual consumption of gasoline increased, the growth rate decreased. The proportion of other energy use in the logistics industry increased. The comprehensive score results show that the obvious sustainable development trend of the logistics industry in Fujian.

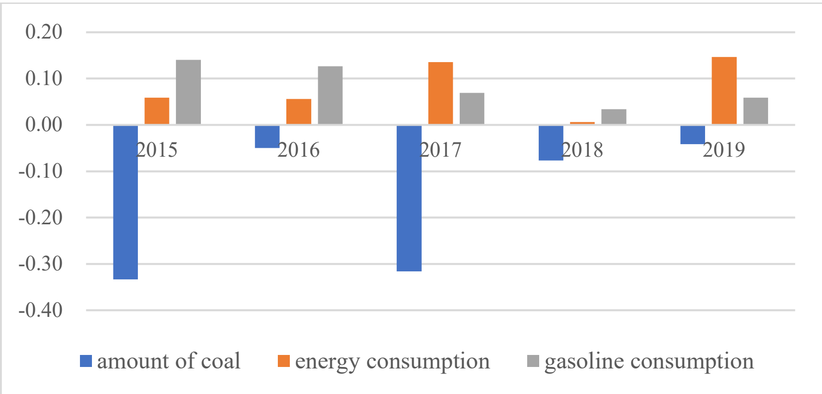

Figure 1. Annual increase in the proportion of energy consumption in Fujian logistics industry.

6. Conclusions

The result of this research allows understanding of the need for regular evaluation of green logistics. In the process of sustainable development of the logistics industry, active monitoring of the weakness in development enhances the marginal benefit and ensures the development of green logistics. Green logistics has become the key to the development of the modern logistics industry. Attention needs to be paid to the macro logistics thinking of the government and to the managerial thinking of logistics operators. The promotion of green energy effectively promotes the development of green logistics. Improving green logistics is possible with the standardization of logistics operations, infrastructure construction, the popularization of green professional knowledge, and the active development plan based on statistical indicators. Thus, the Chinese government needs to continue to promote environmental protection and sustainable green logistics policies.

For future research, the green logistics awareness cognitive evaluation of the industry needs to be added to better understand the actual development of green logistics. Moreover, a comparative study on the evaluation of green logistics development can also be conducted between regions. After all, as the development and requirements of green logistics have become the main trend, in the face of fierce competition in international trade, green logistics is no longer a regional issue.

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